Determining the scale of local adaptation:

What can we learn from a large-scale reciprocal transplant study of an important restoration grass species?

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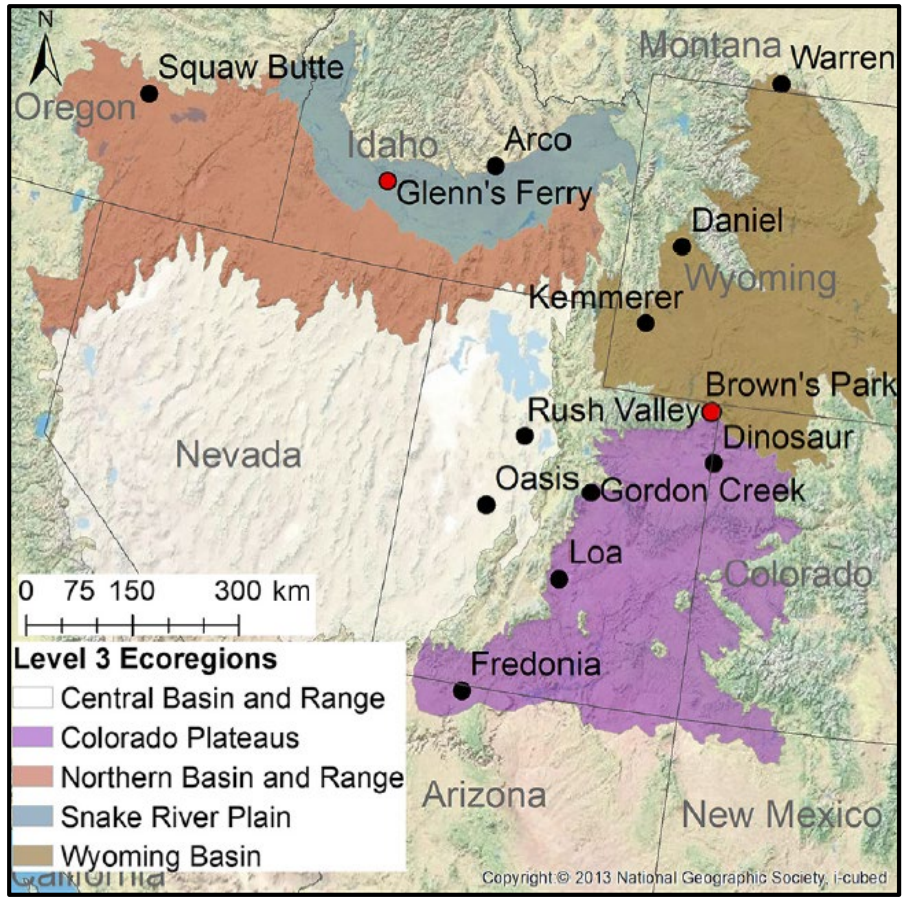
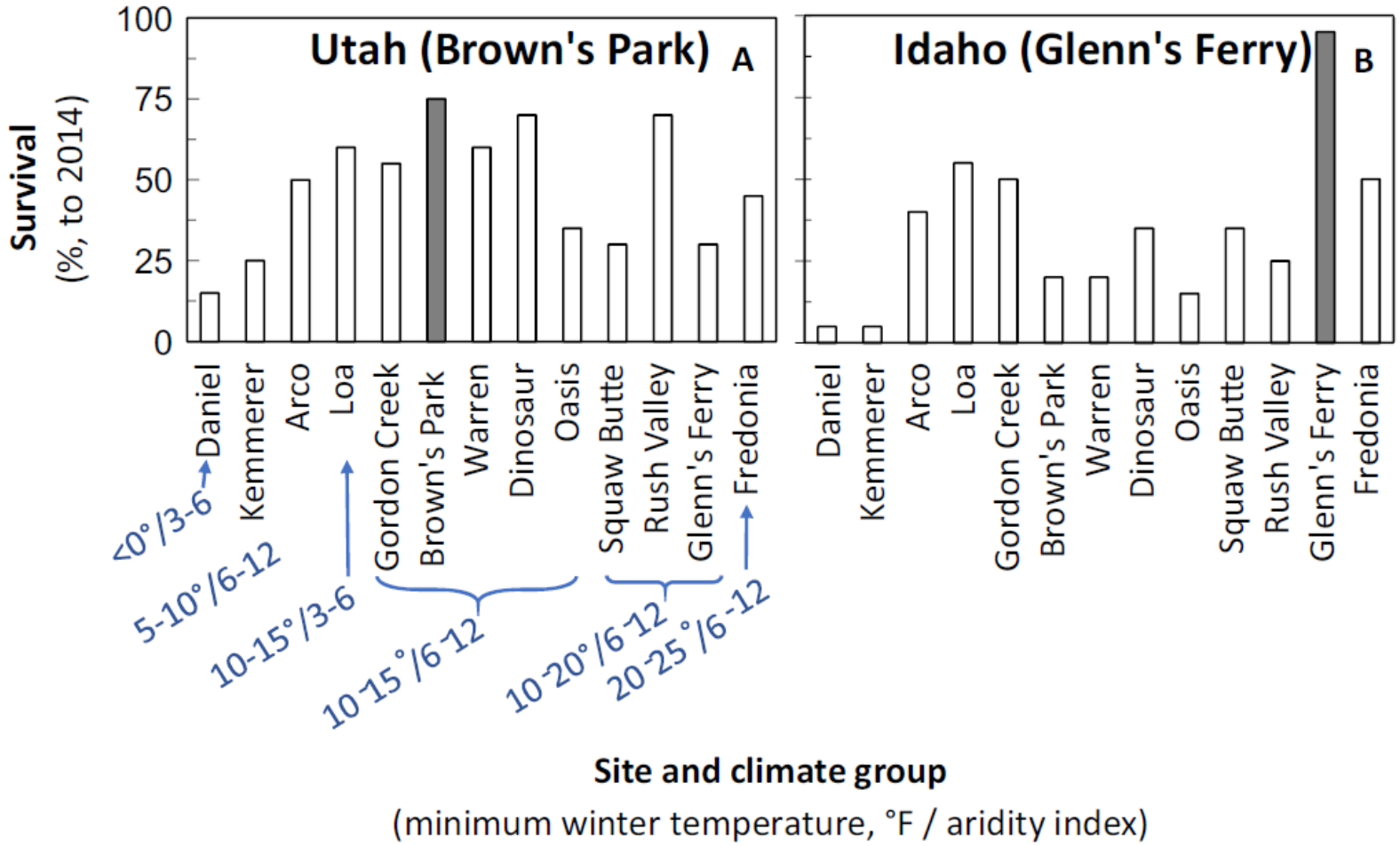
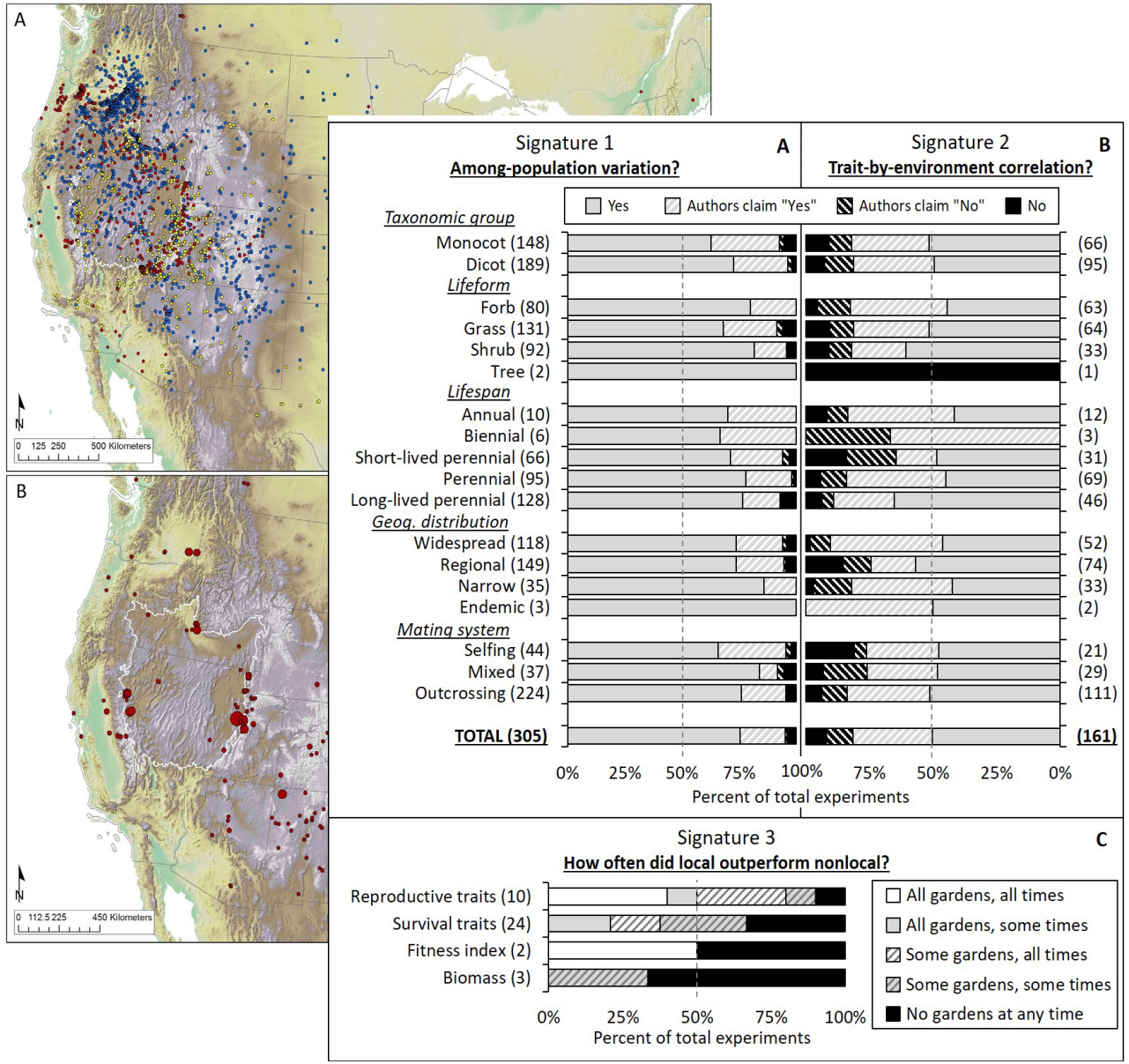
What is local adaptation?





Germino et al. 2019, *Ecological Applications* 29: e01842

How prevalent is local adaptation?



Study	Freq. of LA (^ bounds)
Leimu and Fischer 2008	71%
Hereford 2009	71%
Oduor et al. 2016 - Native	55%
Oduor et al. 2016 - Invasive	45%
Baughman et al. 2019 - GB Surv.	67%
Baughman et al. 2019 - GB Rep.	90%

Baughman et al. 2019, *Ecology and Evolution* 9: 6259-6275

How do we measure local adaptation?

Signatures of local adaptation:

Baughman et al. 2019, *Ecology and Evolution* 9: 6259-6275

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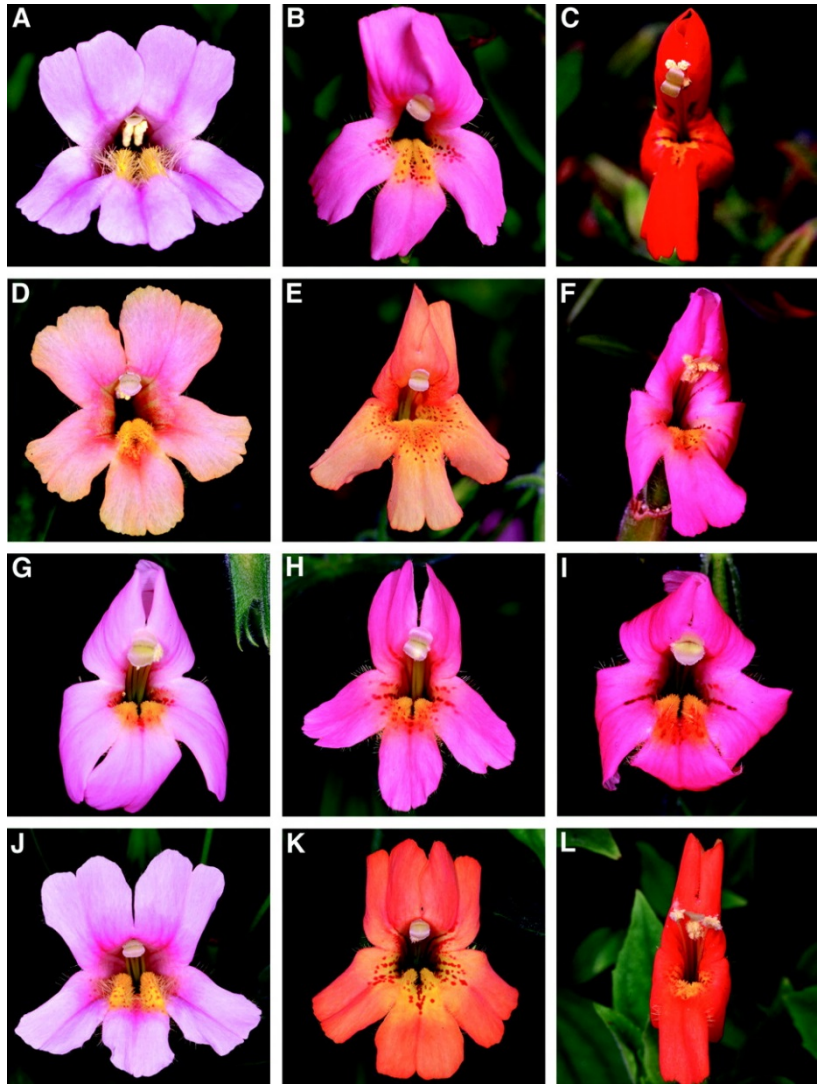
Signatures of local adaptation:

1. Differences among populations in fitness-related traits



Baughman et al. 2019, *Ecology and Evolution* 9: 6259-6275

Schemske and Bradshaw 1999, *PNAS* 96: 11910-11915

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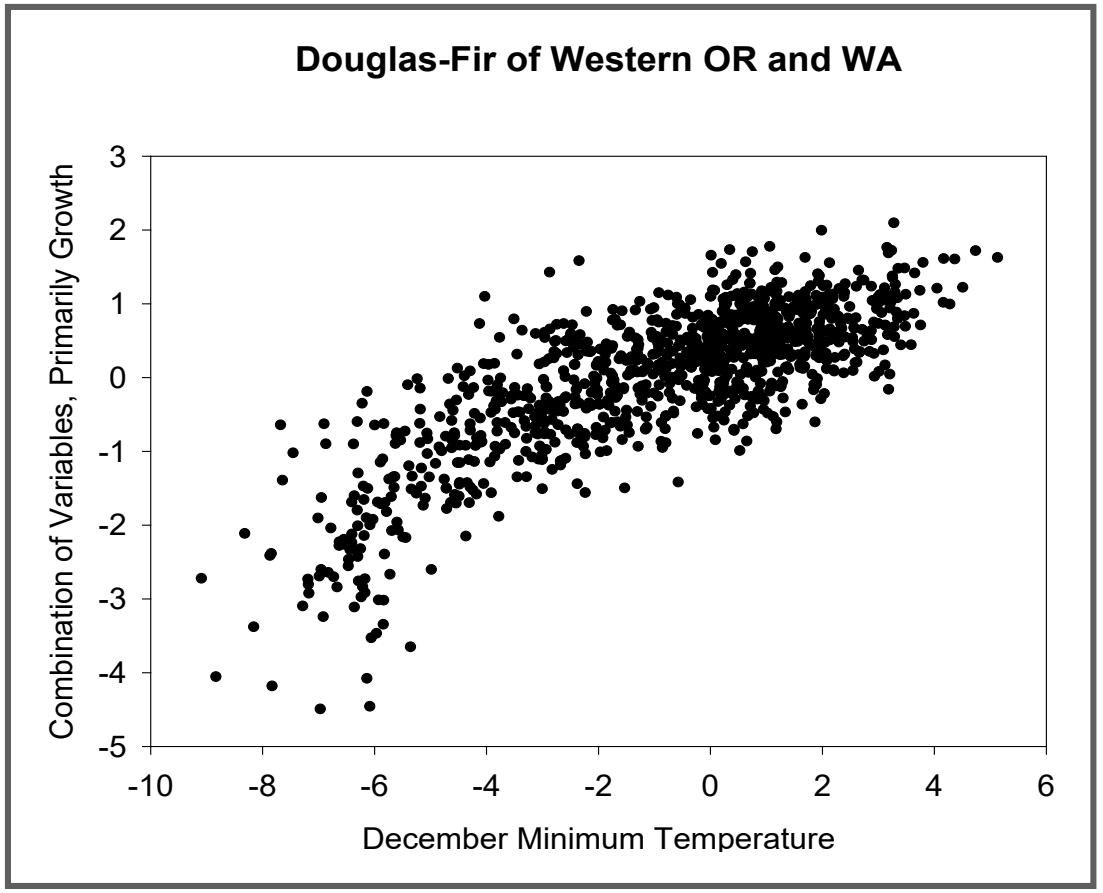
2. Correlations between these trait values and environmental or other habitat-related variables



St. Clair et al. 2005, *Annals of Botany* 96: 1199-1214

AKA: Transfer function

One* garden, many sources

Baughman et al. 2019, *Ecology and Evolution* 9: 6259-6275

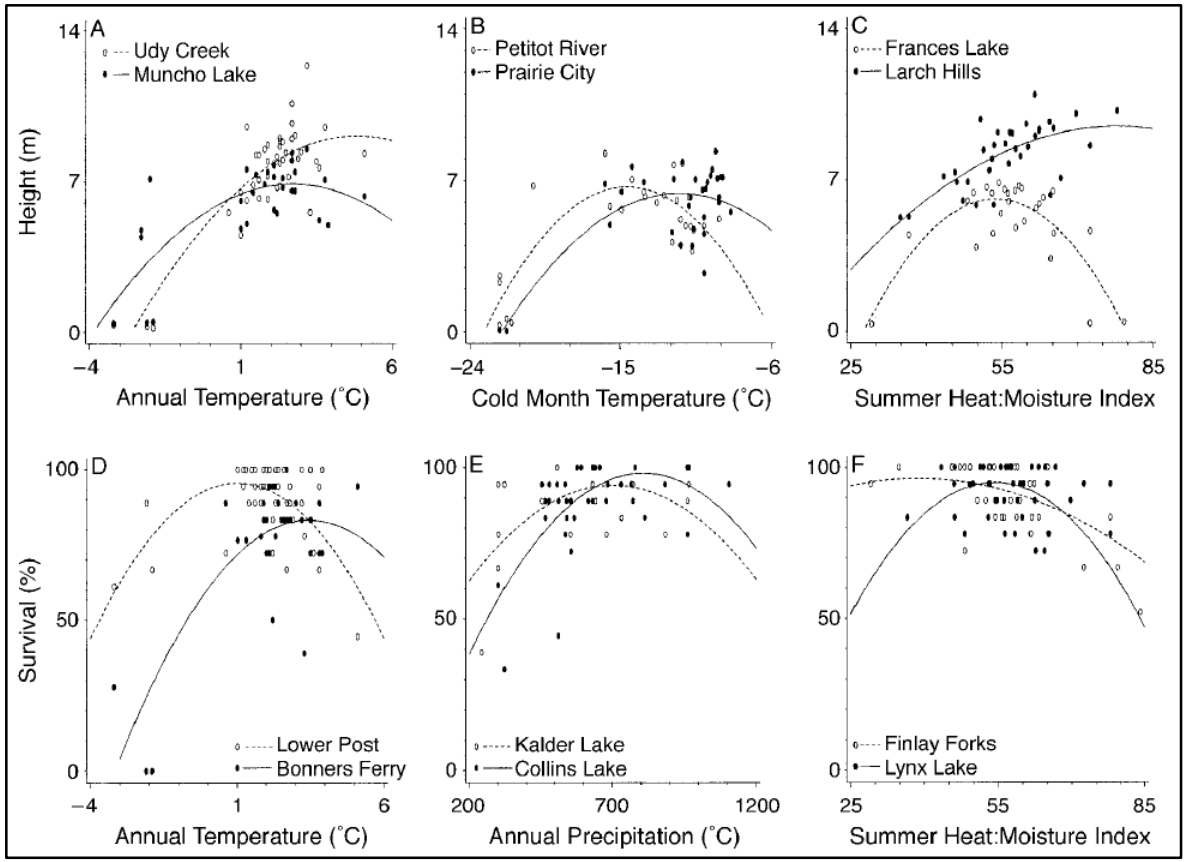
How do we measure local adaptation?

Signatures of local adaptation:

1. Differences among populations in fitness-related traits
2. Correlations between these trait values and environmental or other habitat-related variables
3. Higher fitness of local over nonlocal populations in the local environment

AKA: Response function

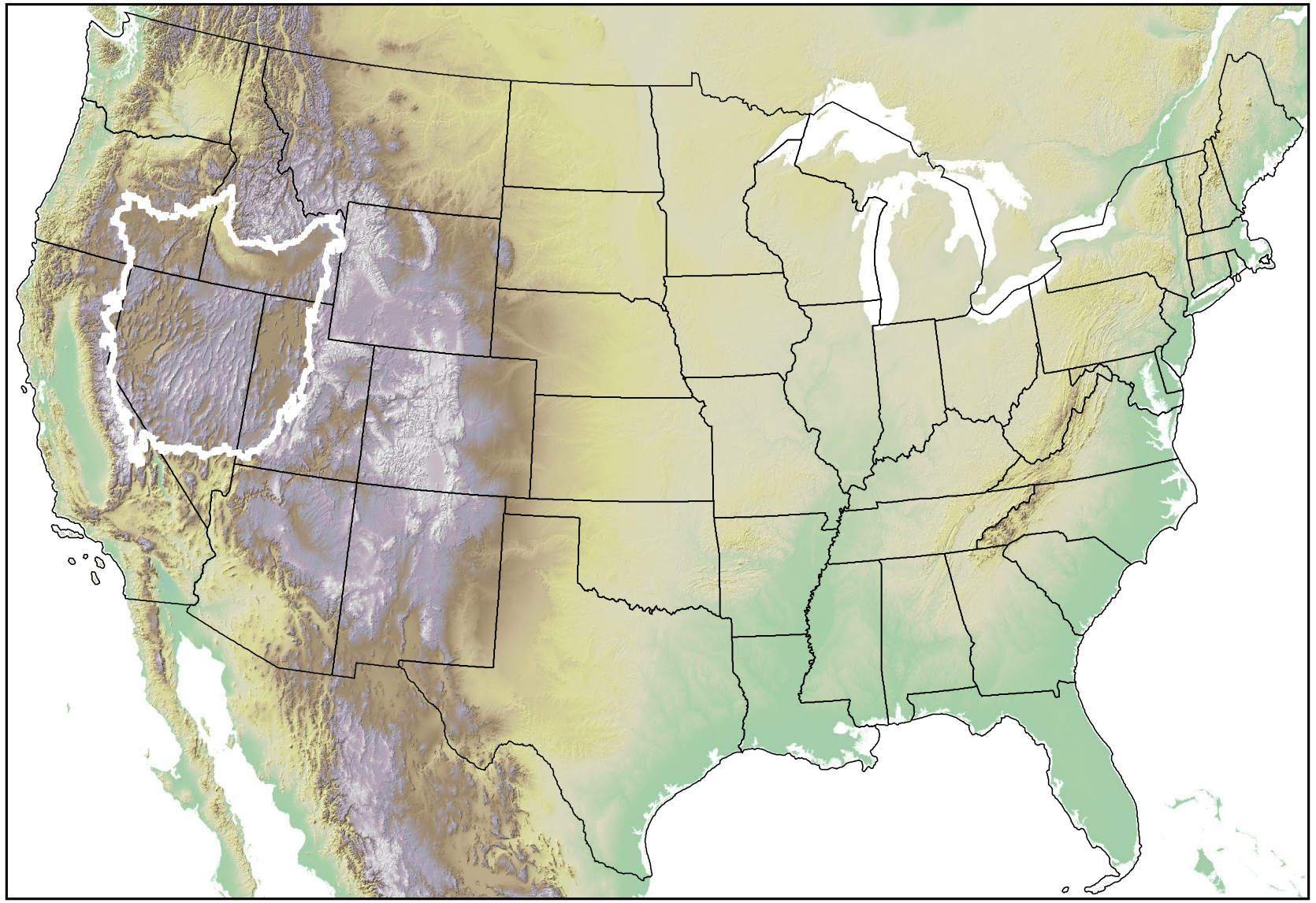
One* source, many gardens



Rehfeldt et al. 1999, *Ecological Monographs* 69: 375-407

Baughman et al. 2019, *Ecology and Evolution* 9: 6259-6275

Restoration in the Great Basin of the United States



- The Great Basin is a large area: 550k km^2 – 75% controlled by the Federal Government
- Extremely topographically variable (750-4000 m) - ranges in aridity from salt desert to montane forest (50-600 mm)
- Severely threatened by fire – driven by invasive annuals and climate change – fire return intervals shifted from 100-150 y to 30-50 y, and even 7-11 y in some locations
- Bureau of Land Management spends over $600m per year on post-fire restoration – mostly in the Great Basin

Seed sourcing in the Great Basin

Squirreltail

Native bluegrasses

Indian ricegrass

Bluebunch wheatgrass

Snake River wheatgrass

Thickspike wheatgrass

Basin wildrye

Western wheatgrass

Jones and Larson 2005, USDA Forest Service Proceedings RMRS-P-38

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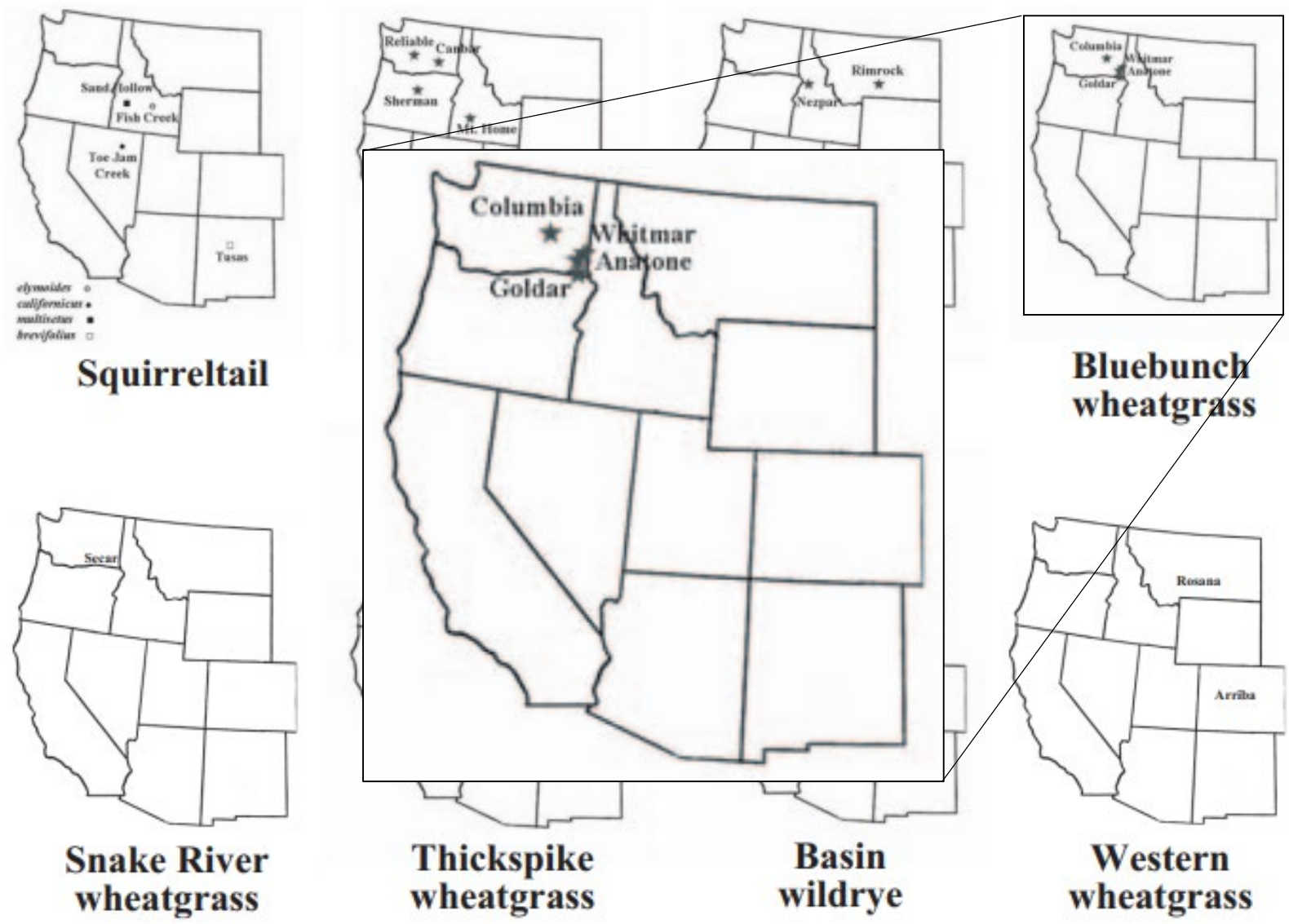

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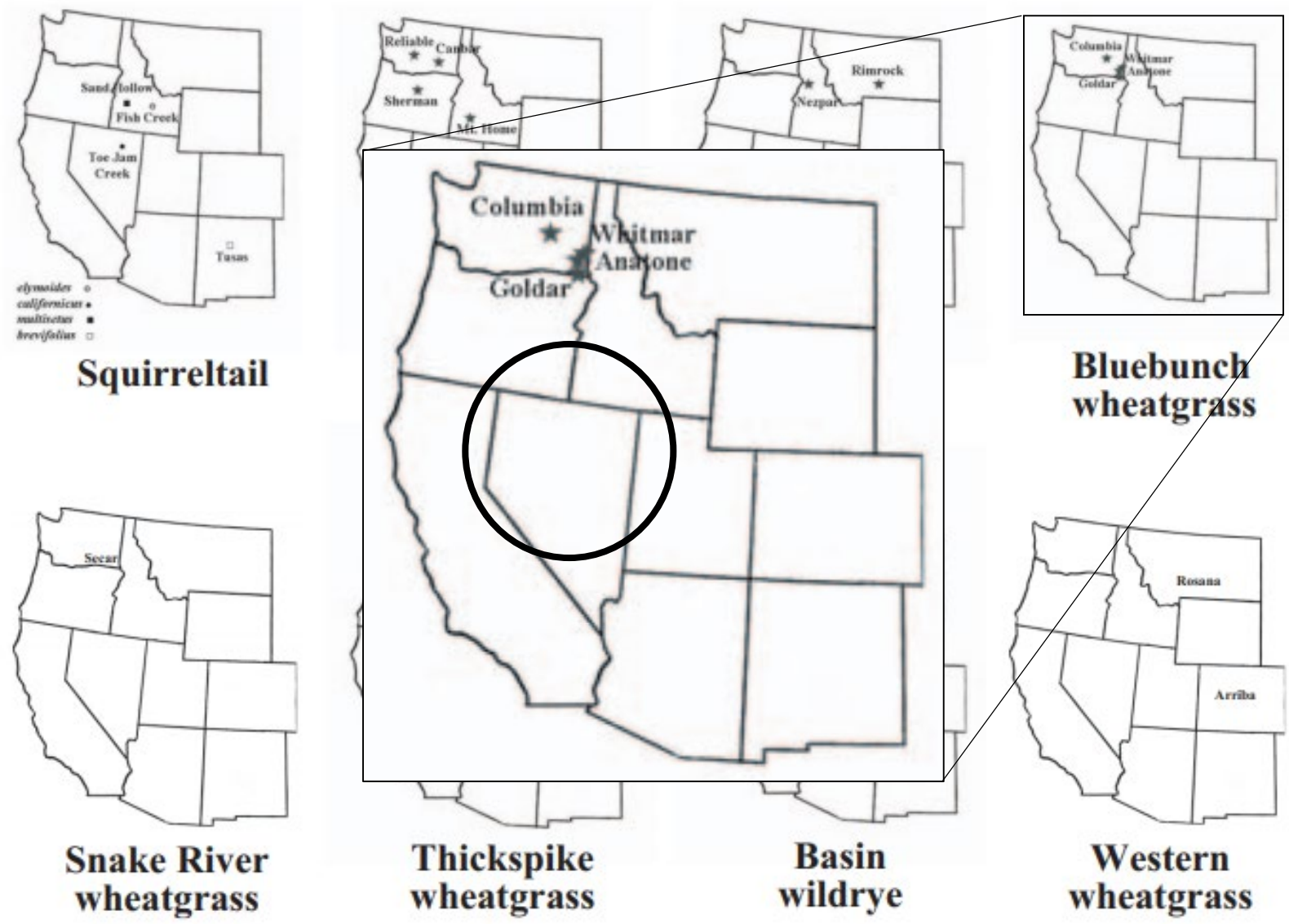

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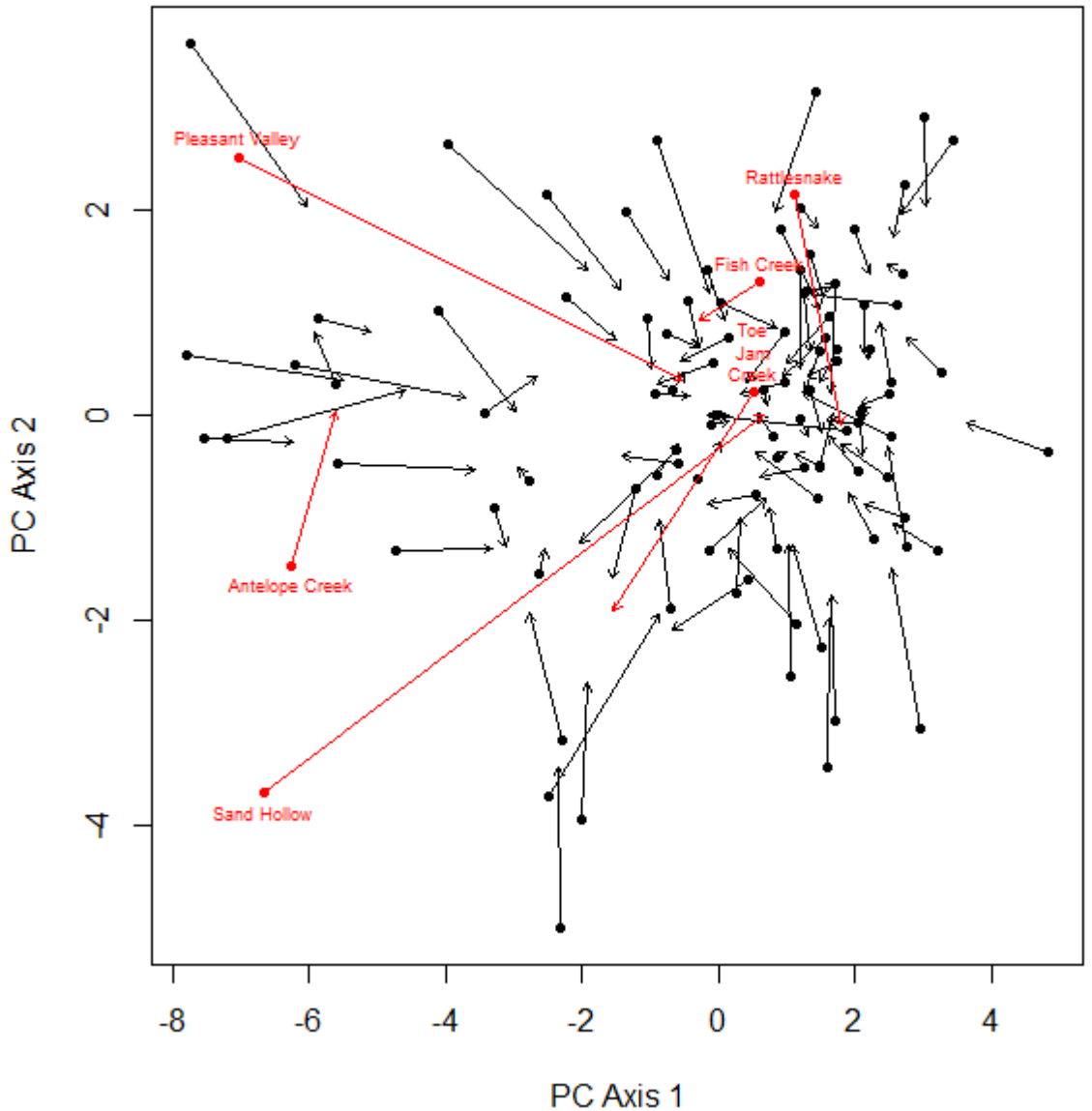
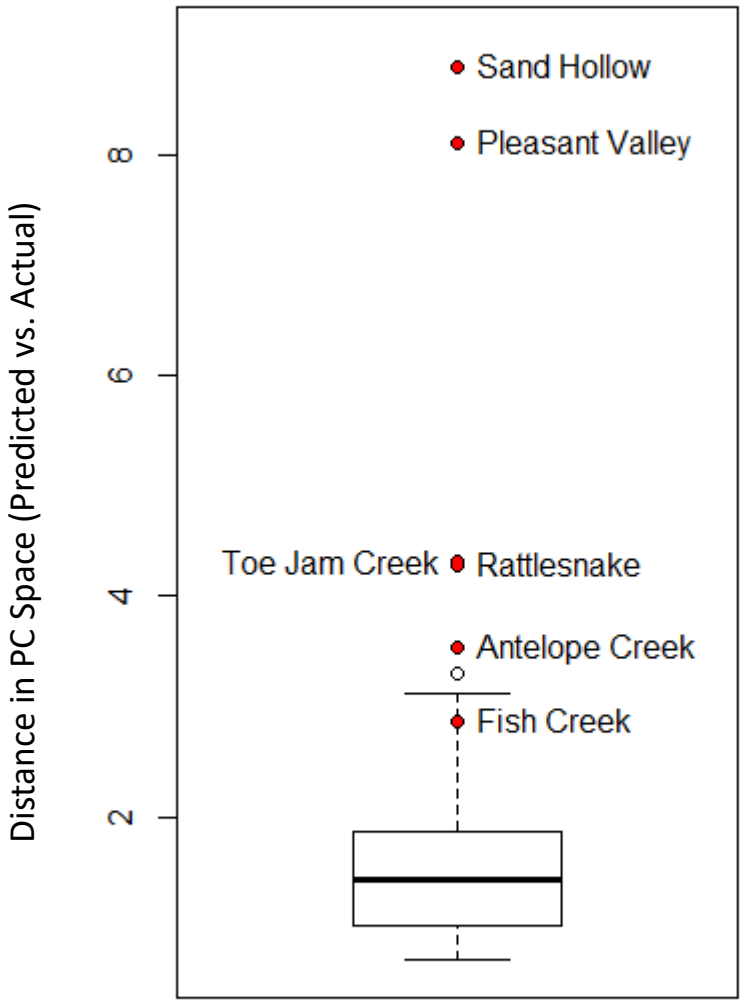
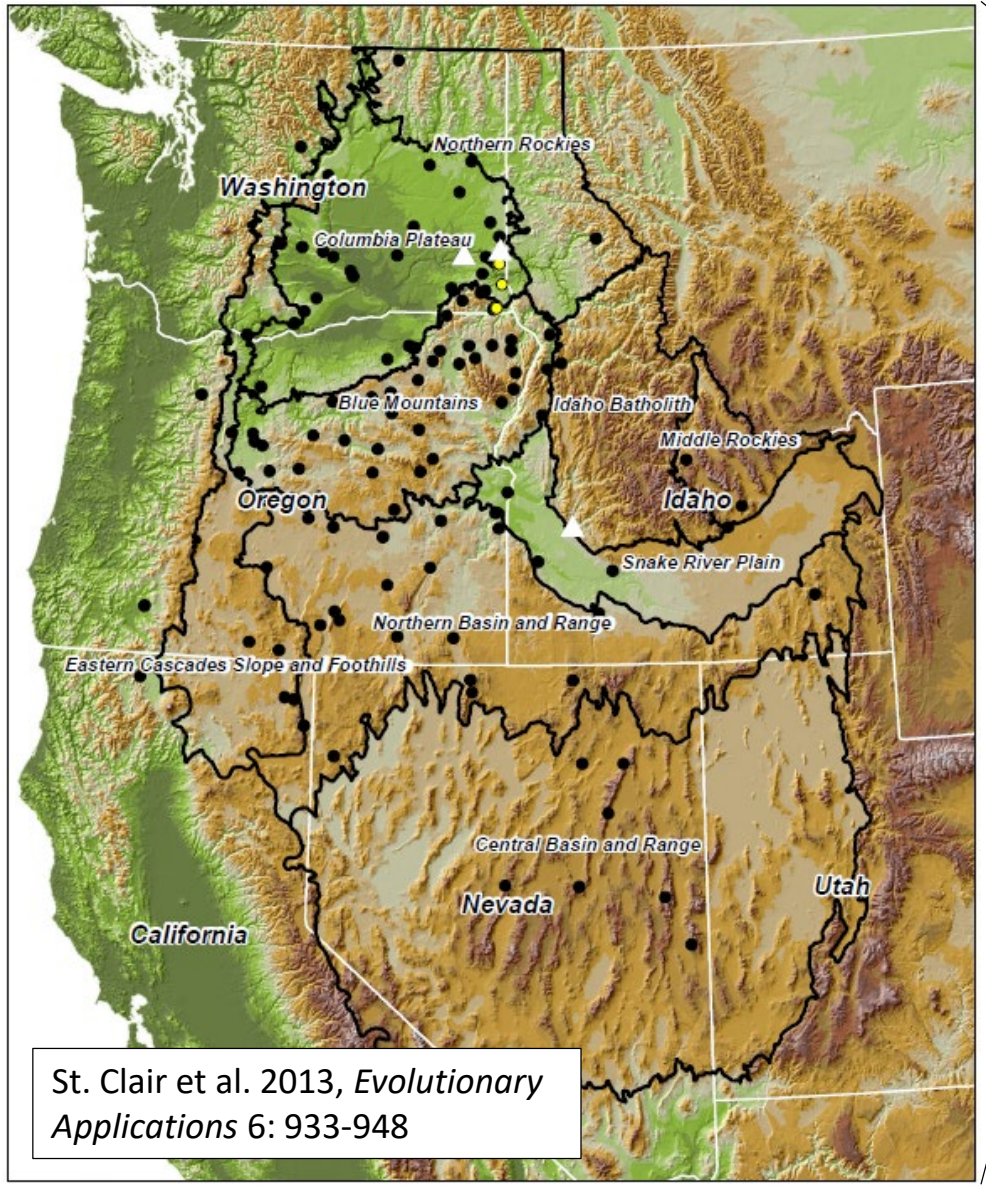
Seed sourcing in the Great Basin – *Elymus elymoides*



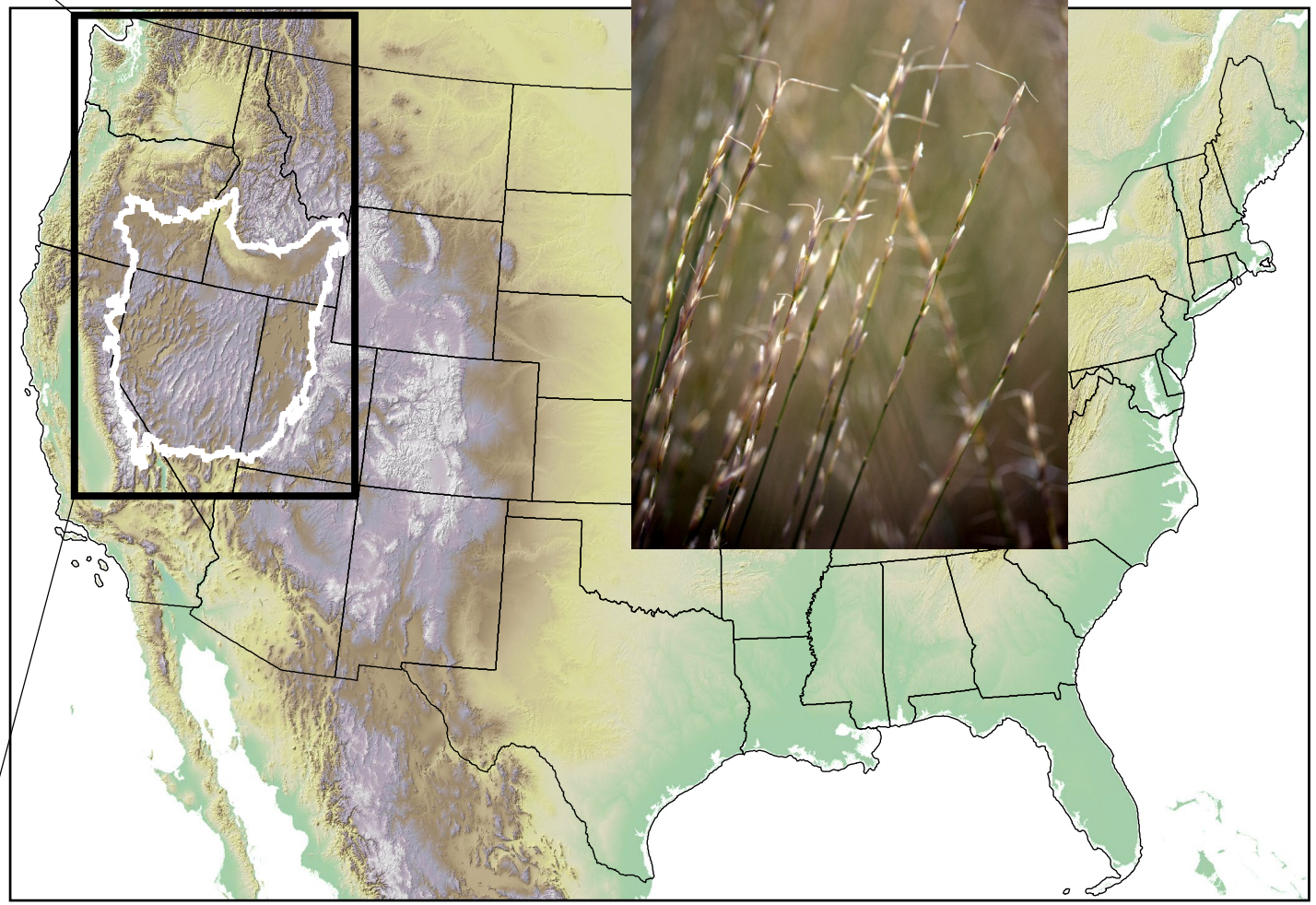


Ott et al. unpublished data

Bluebunch wheatgrass – important restoration species



St. Clair et al. 2013, *Evolutionary Applications* 6: 933-948



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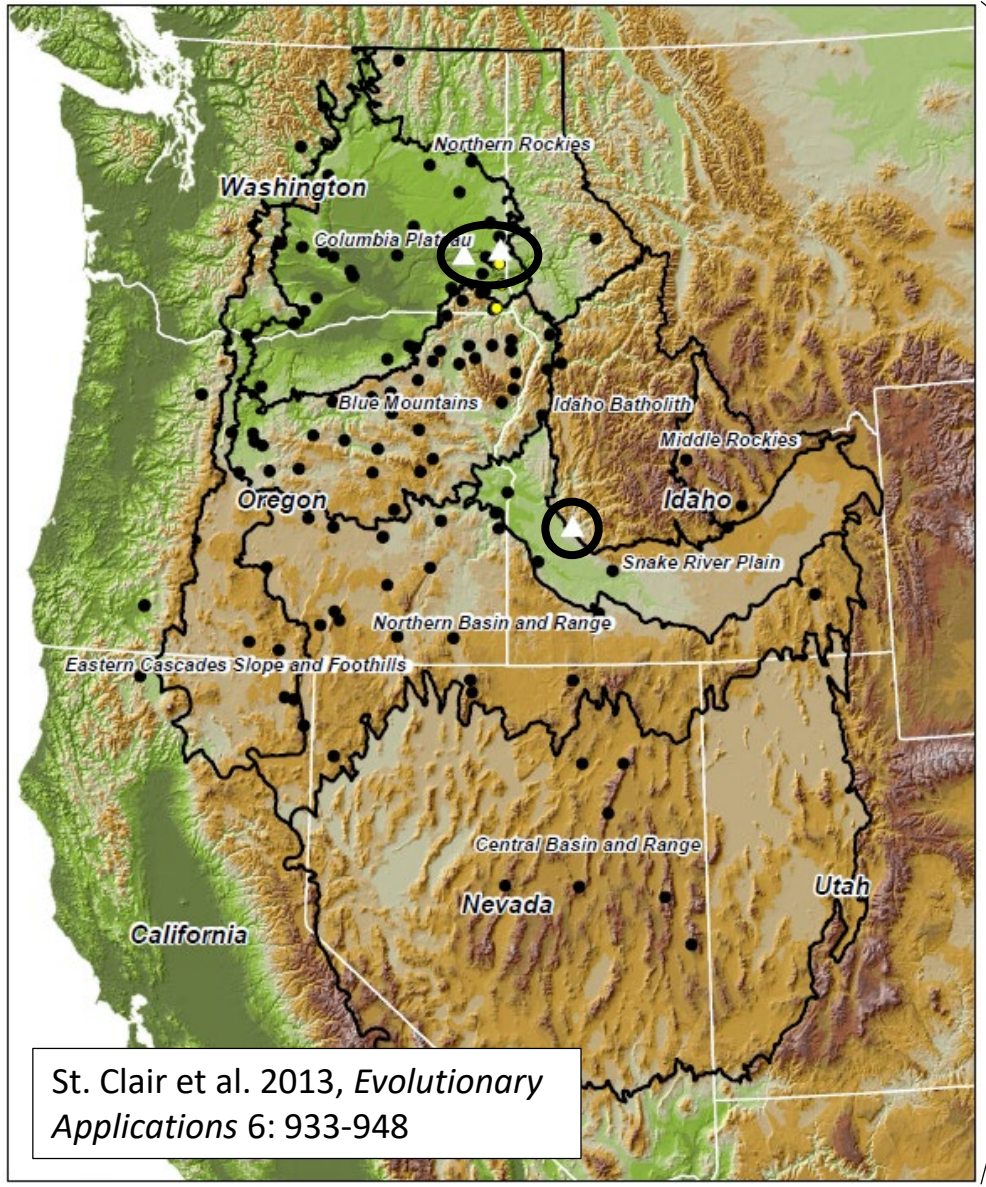

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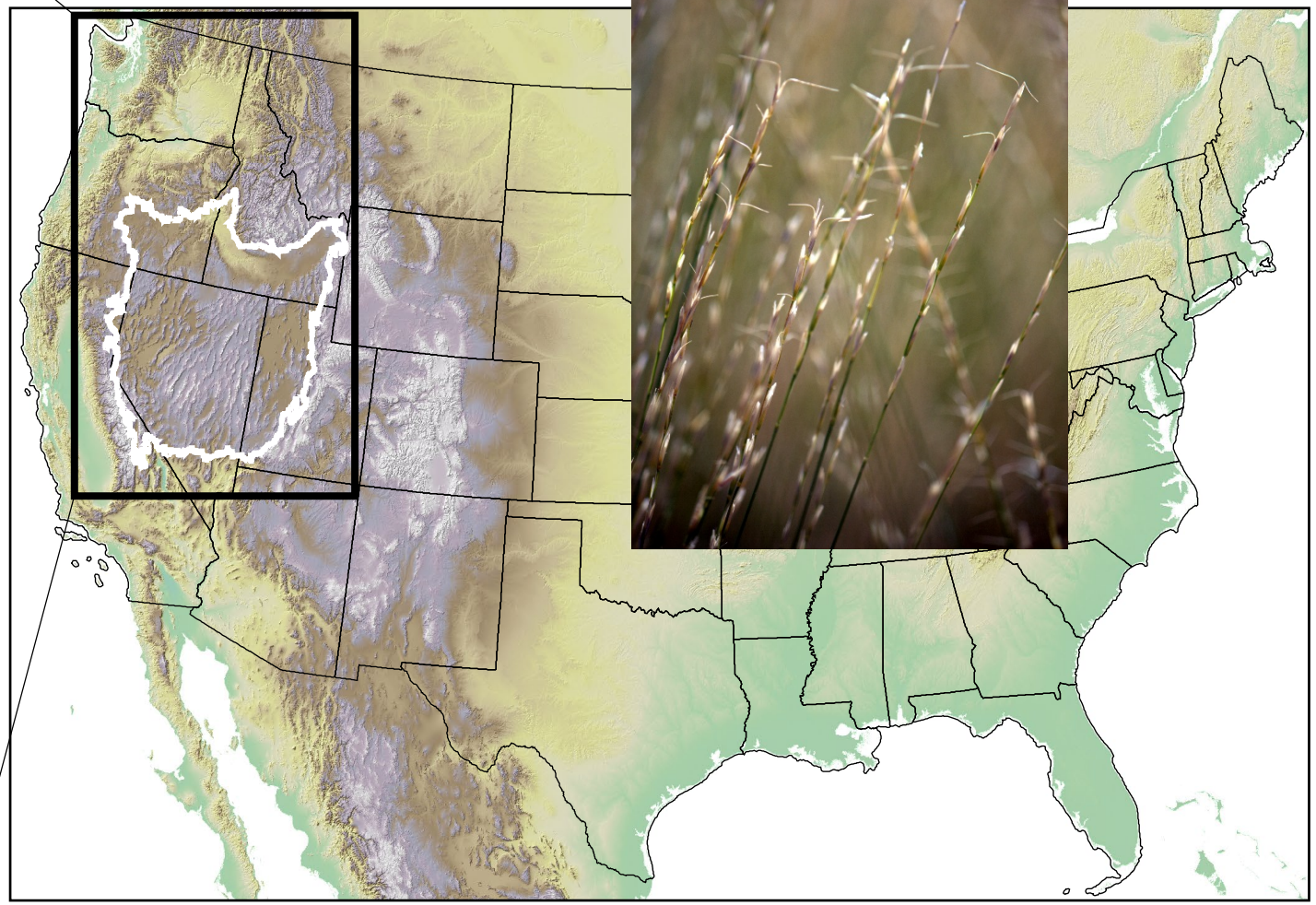

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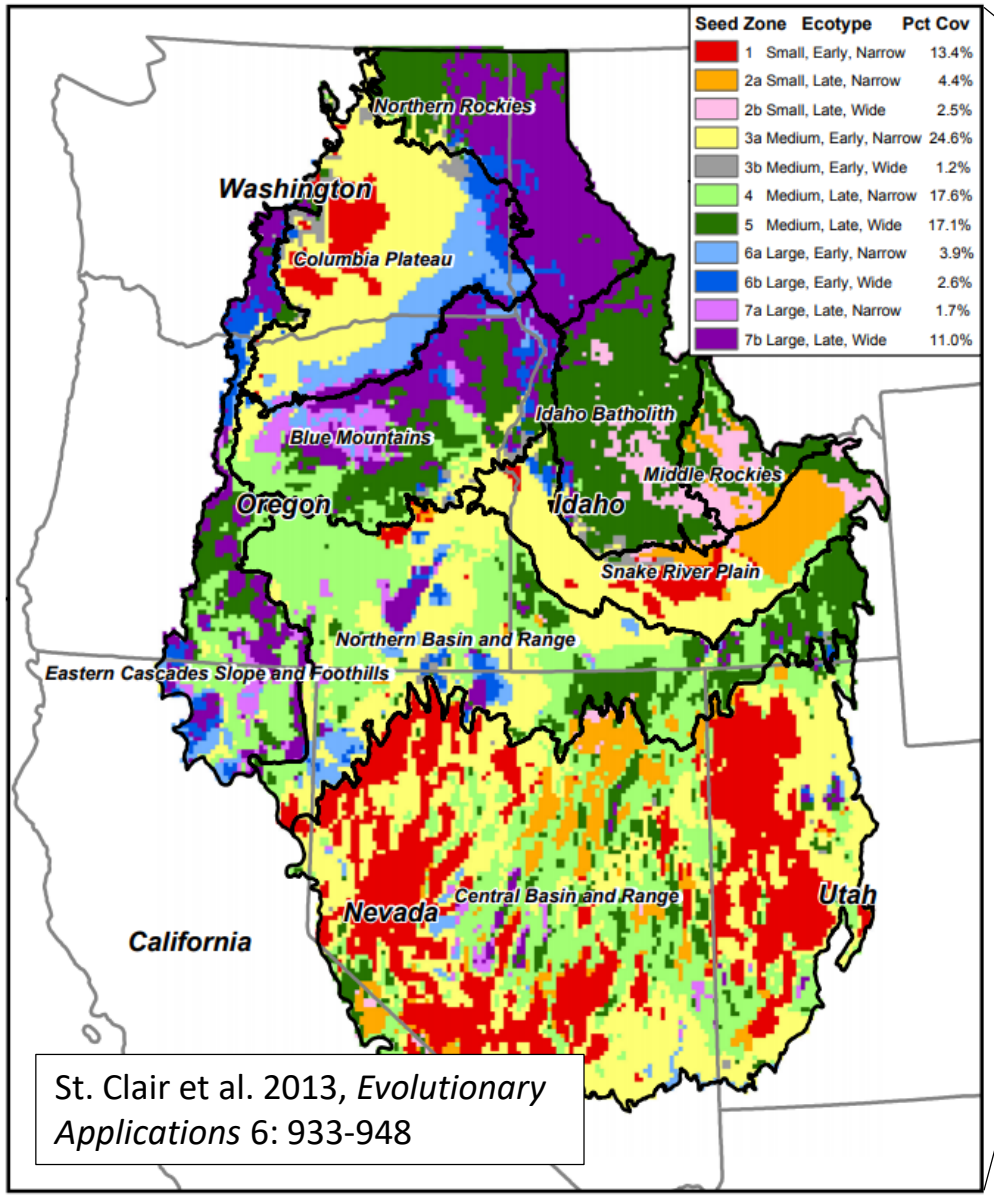

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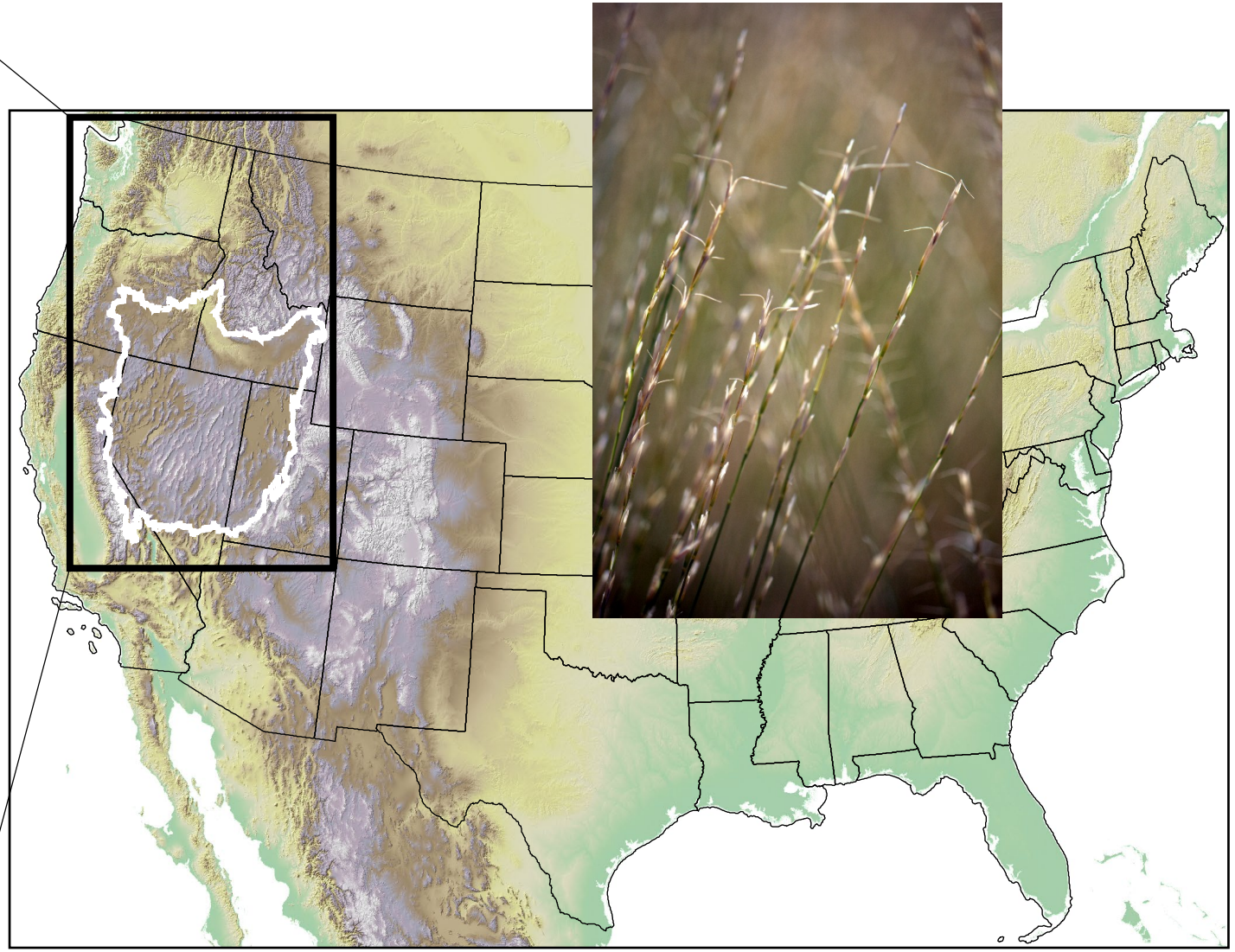
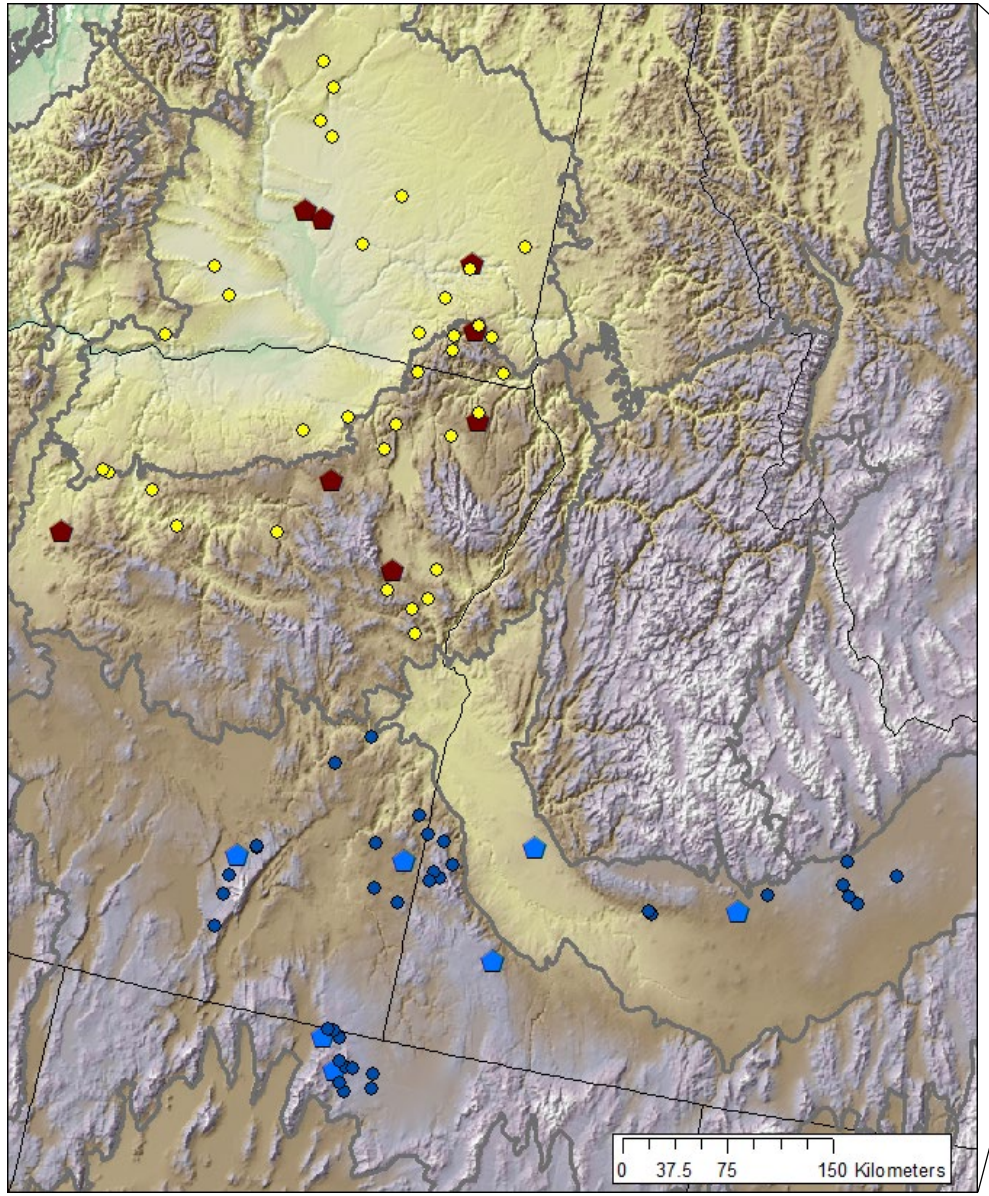
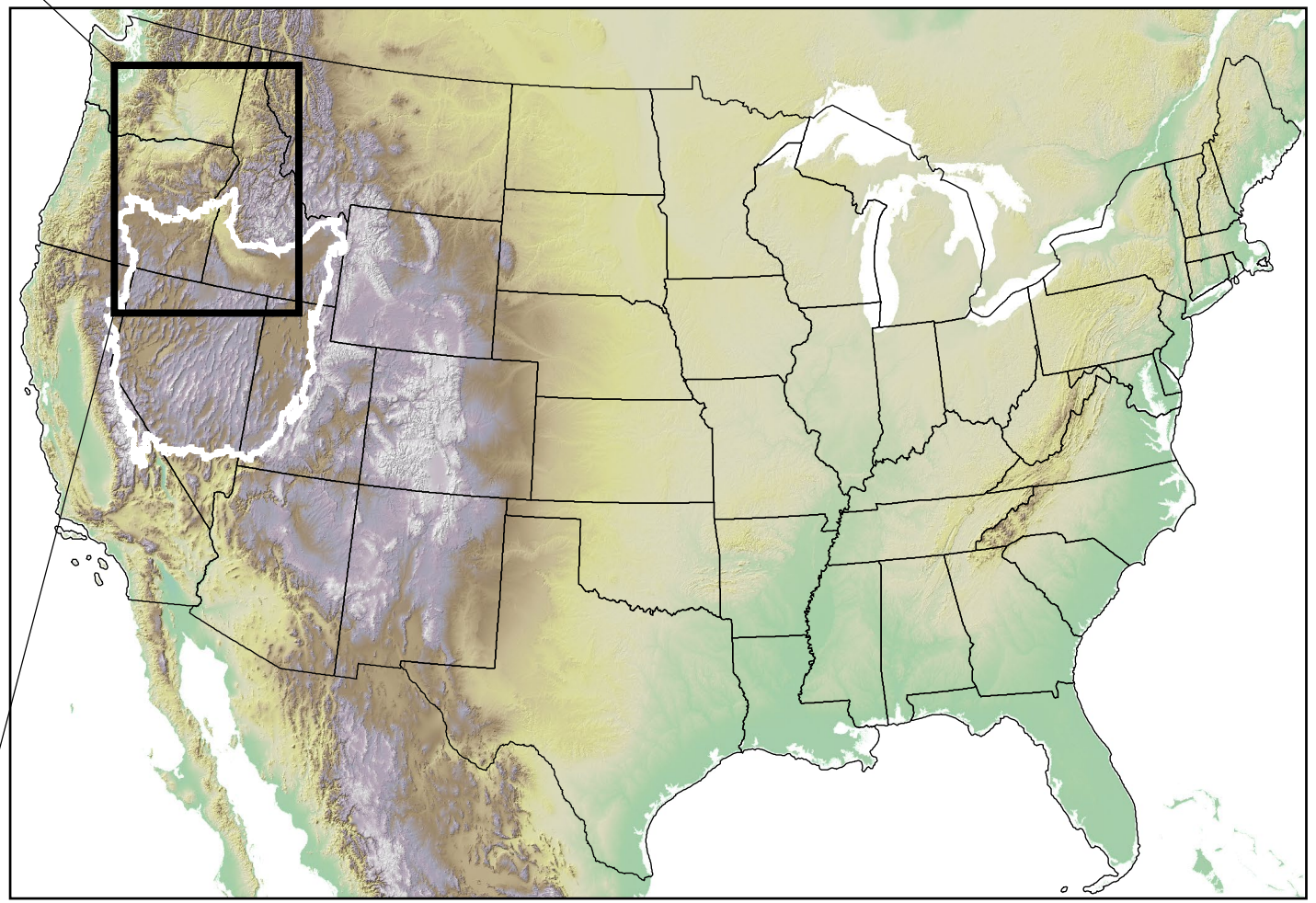


Bluebunch wheatgrass – Reciprocal transplant study





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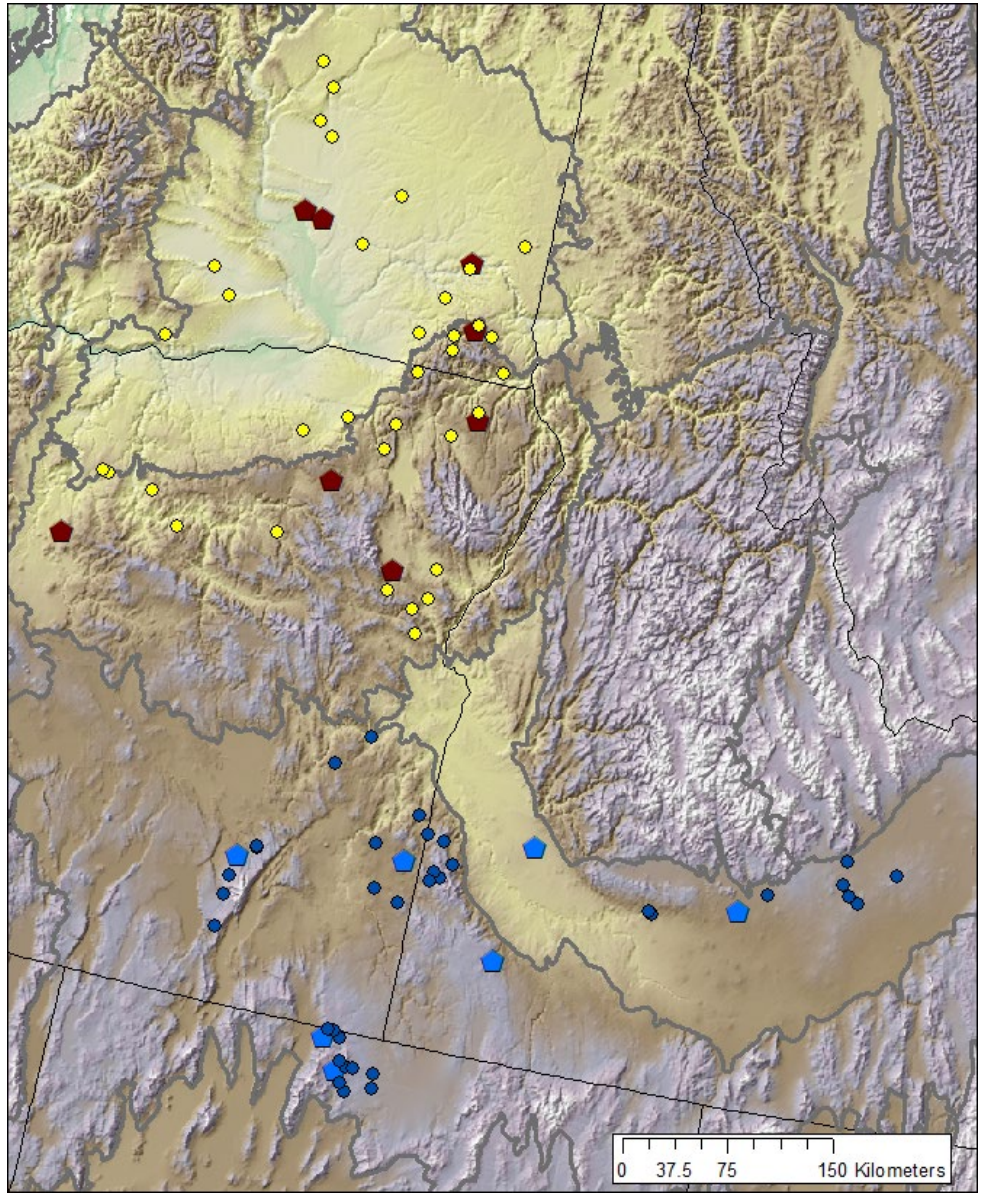
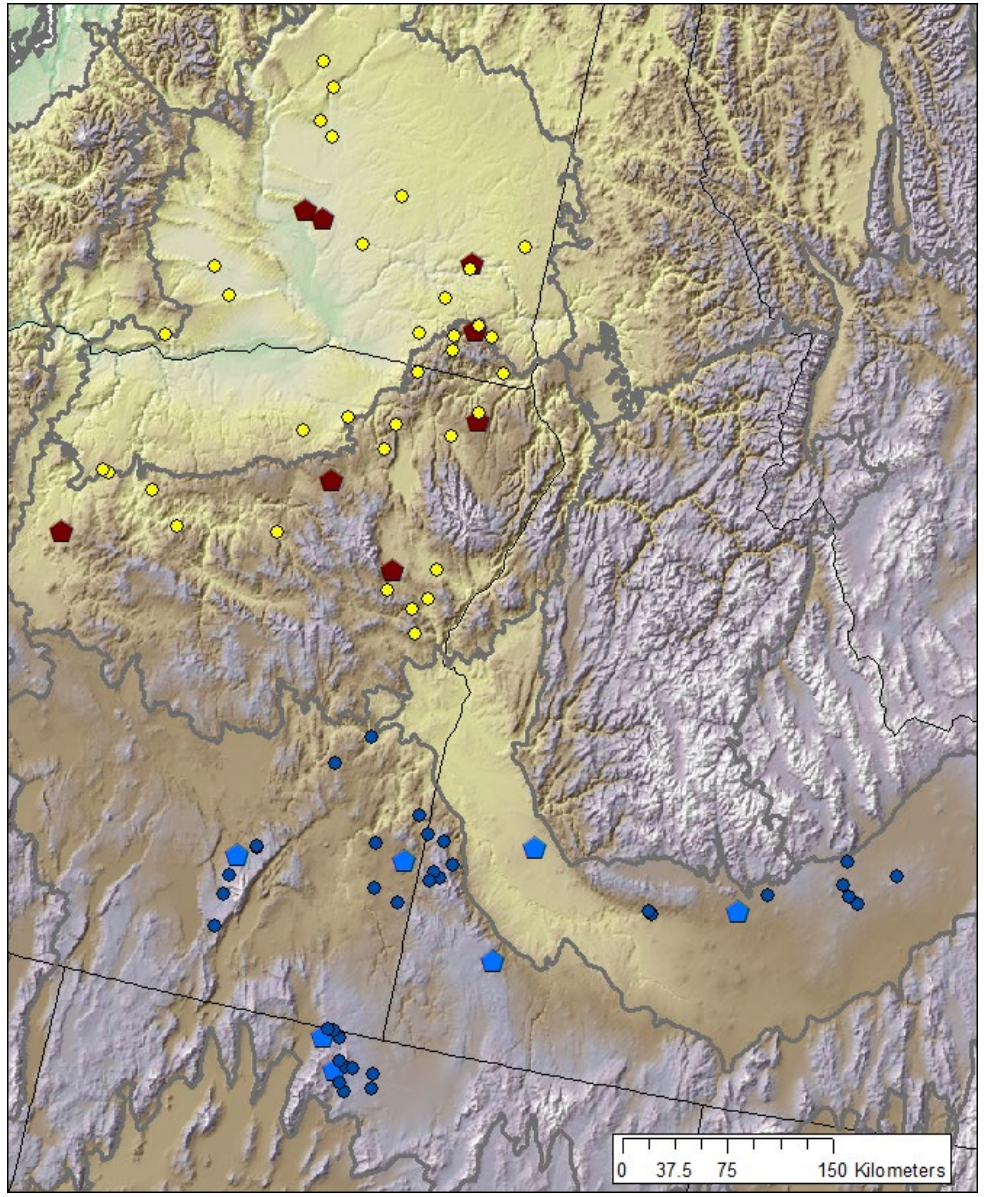


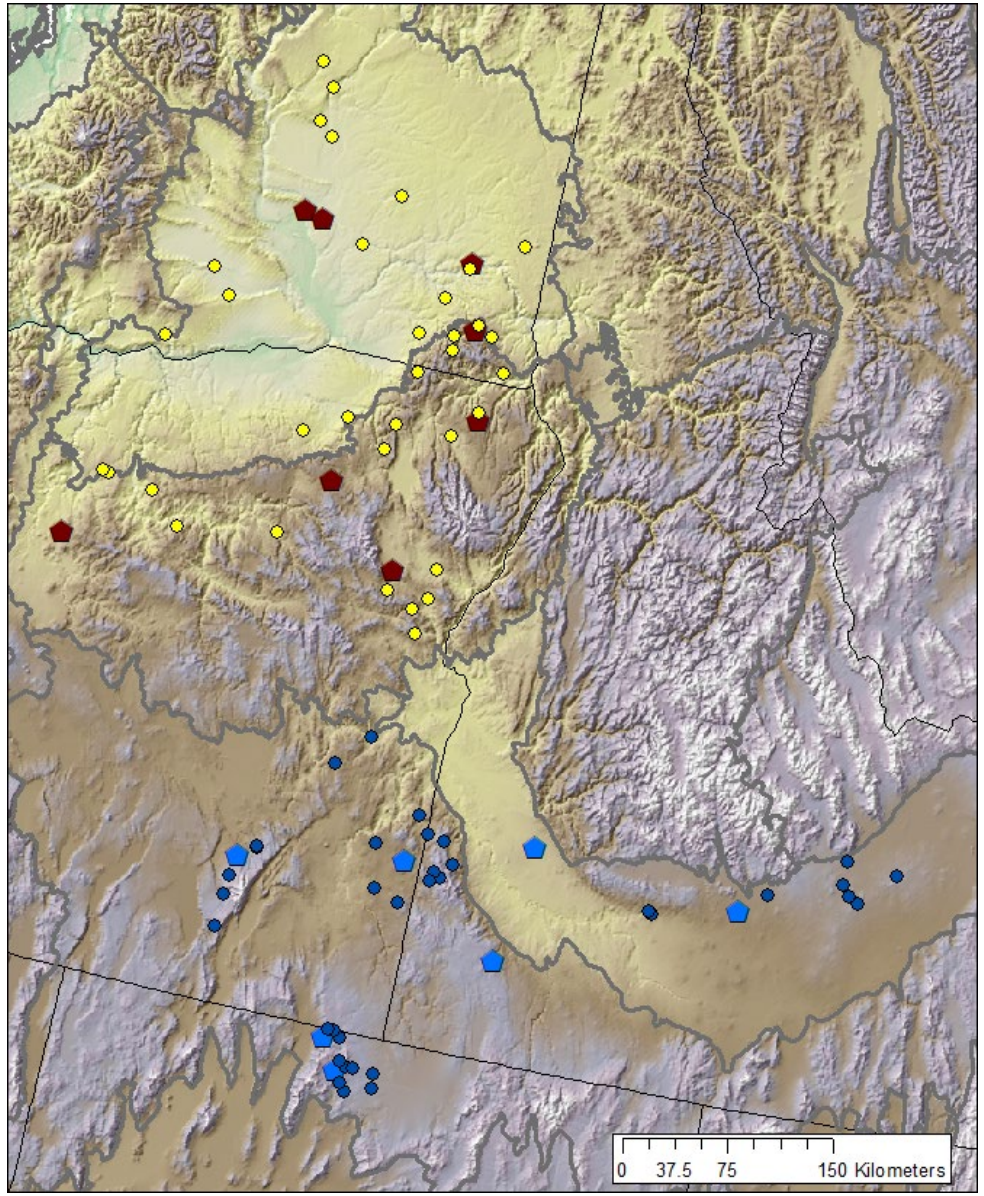
Kas Dumroese, Jeremy Pinto, Jessica Irwin, Chris Poklemba, Matt Fisk, Jameson Rigg, Alexis Malcomb, Katherine Prive, Nancy Shaw, Berta Youtie, Jeff Ott, Bobby Benson, Kimberly Stocks, Matt Germino, Jill Pavlik, Lia Leibman, Chris Link, Charlie Abeles, Andrea Balch, Allison Busier, Tessa Bartz **and many more!**

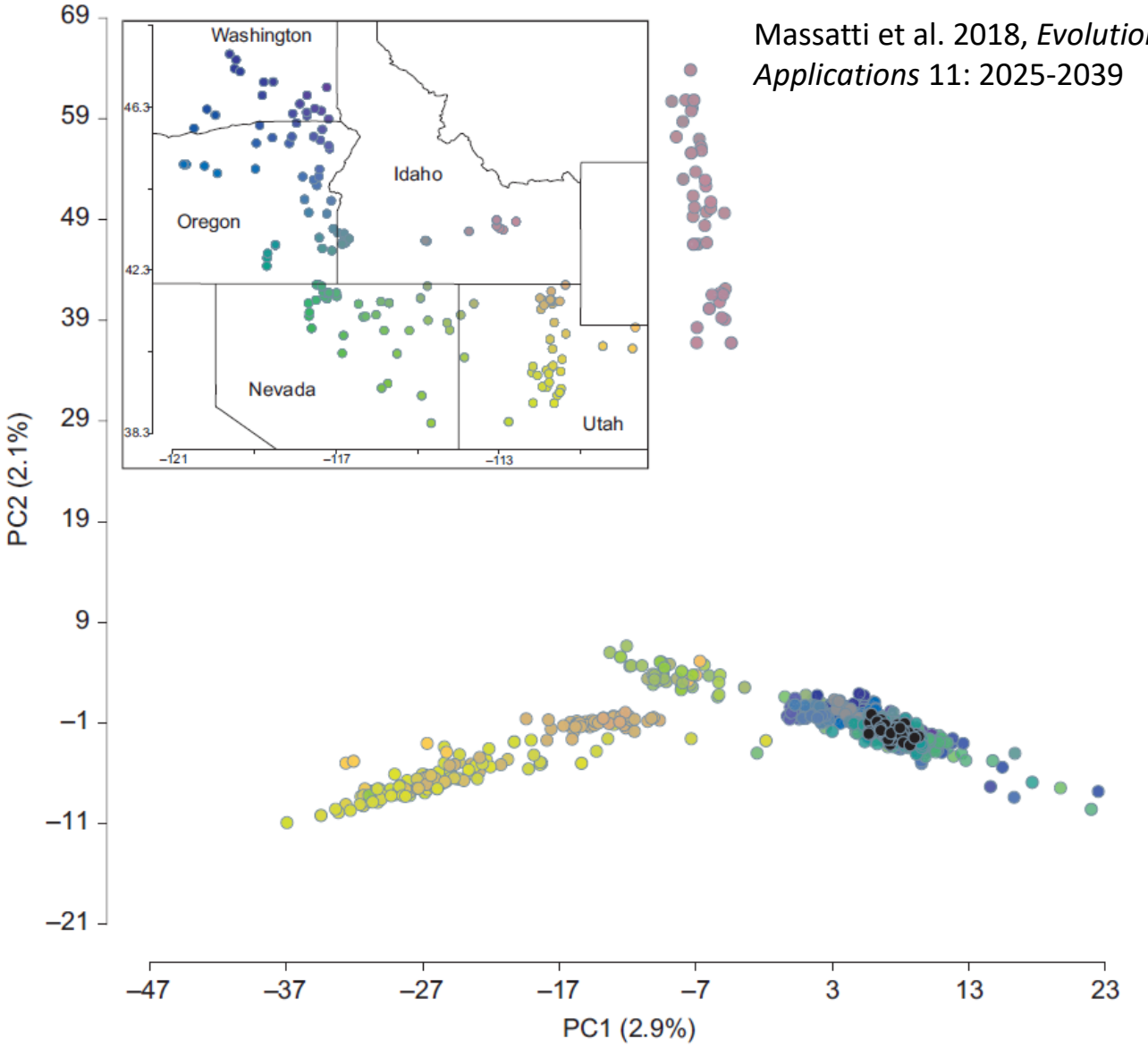
Bluebunch wheatgrass – Reciprocal transplant study



- 2 experimental regions (transects)
- 15 common garden sites – 8 in the northern transect, 7 in the southern transect
- 38 natural populations planted across all sites within each transect (78 total), as well as 3 commercial germplasms (not discussed here)
- Over 15,000 experimental plants were installed
- Site monitoring began in 2015 and continues for 14 of the 15 original sites
- Data in this talk will focus on 2017, the last year where all original measurements were taken

Bluebunch wheatgrass – Reciprocal transplant study





Massatti et al. 2018, *Evolutionary Applications* 11: 2025-2039

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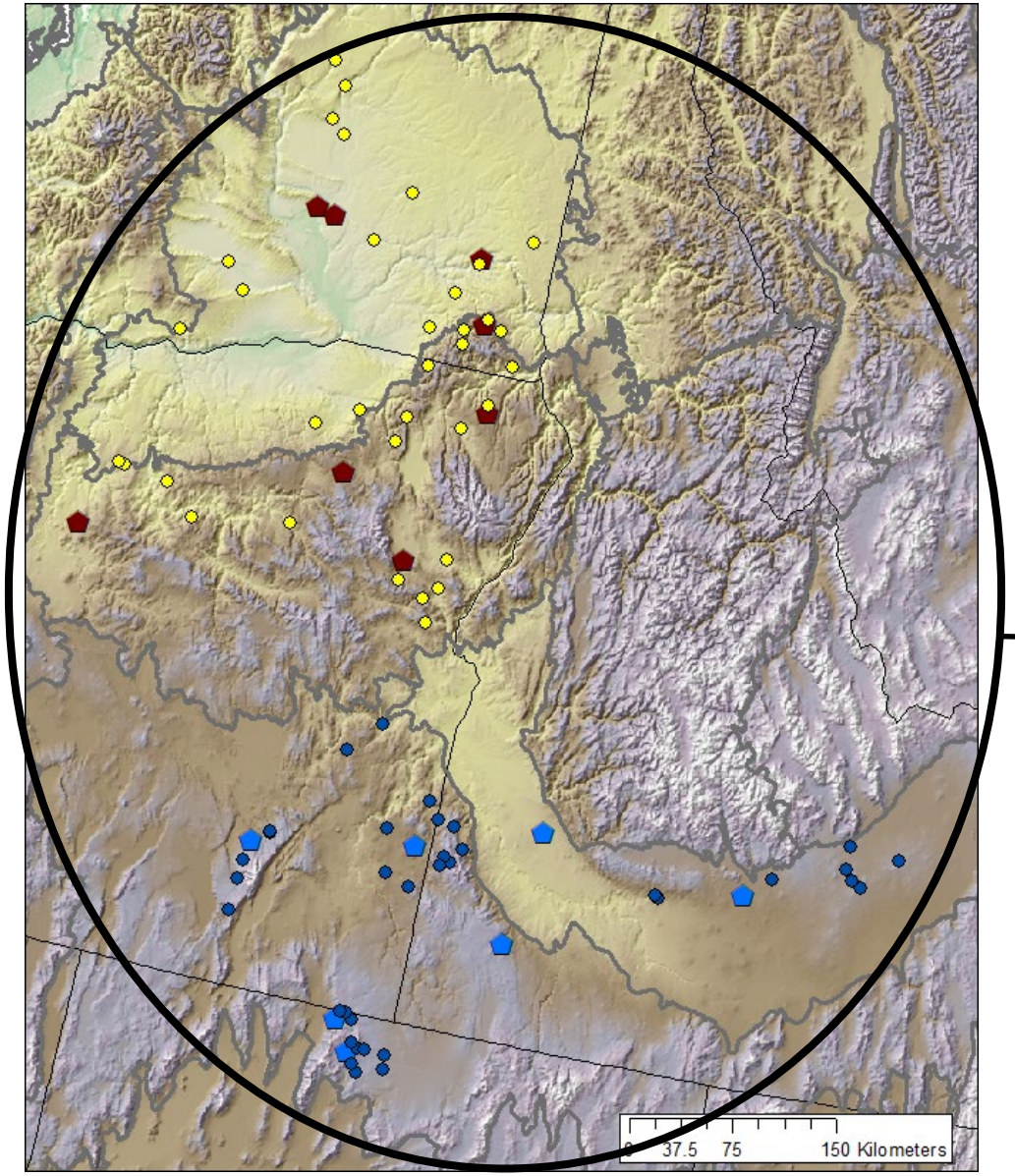

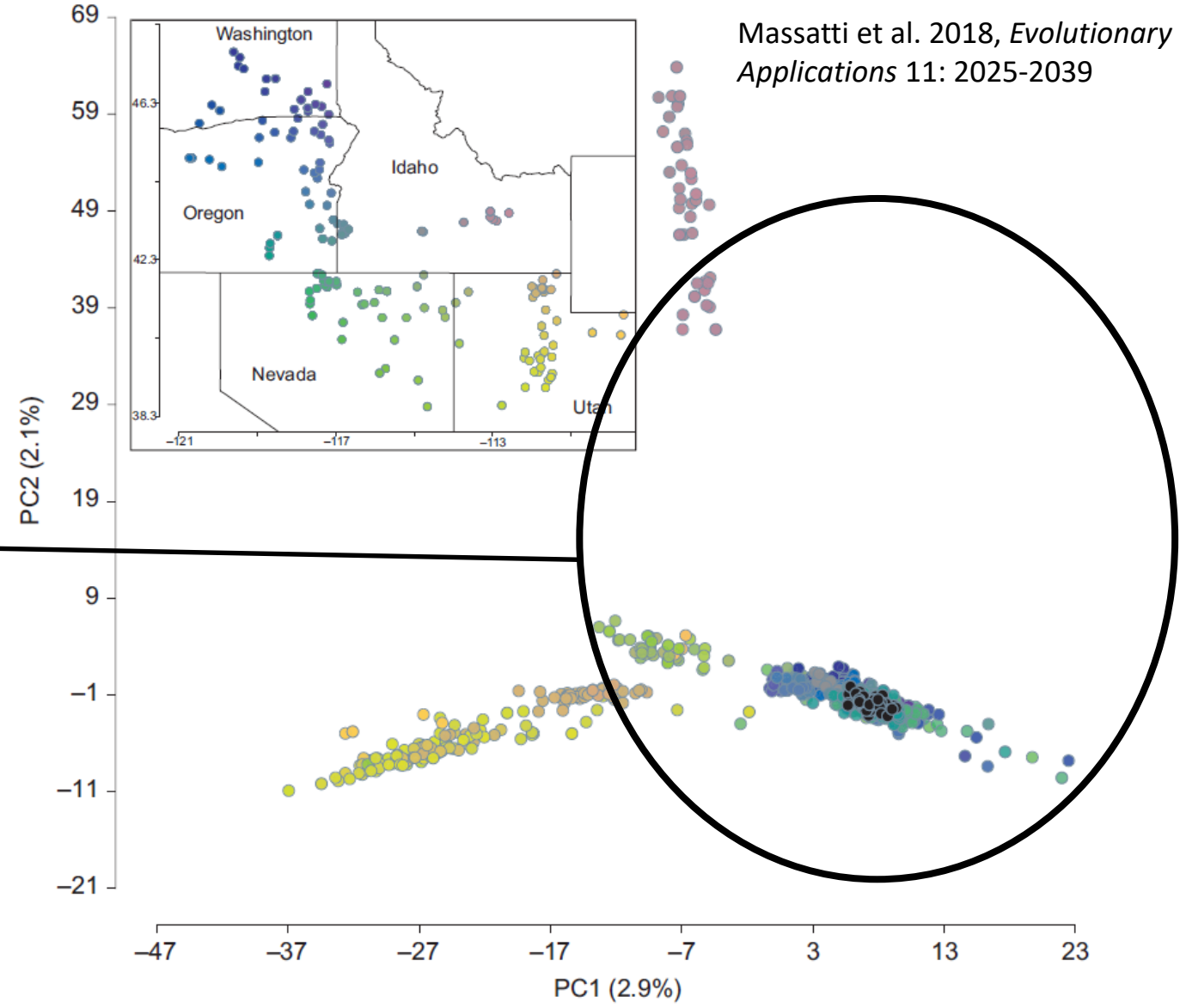

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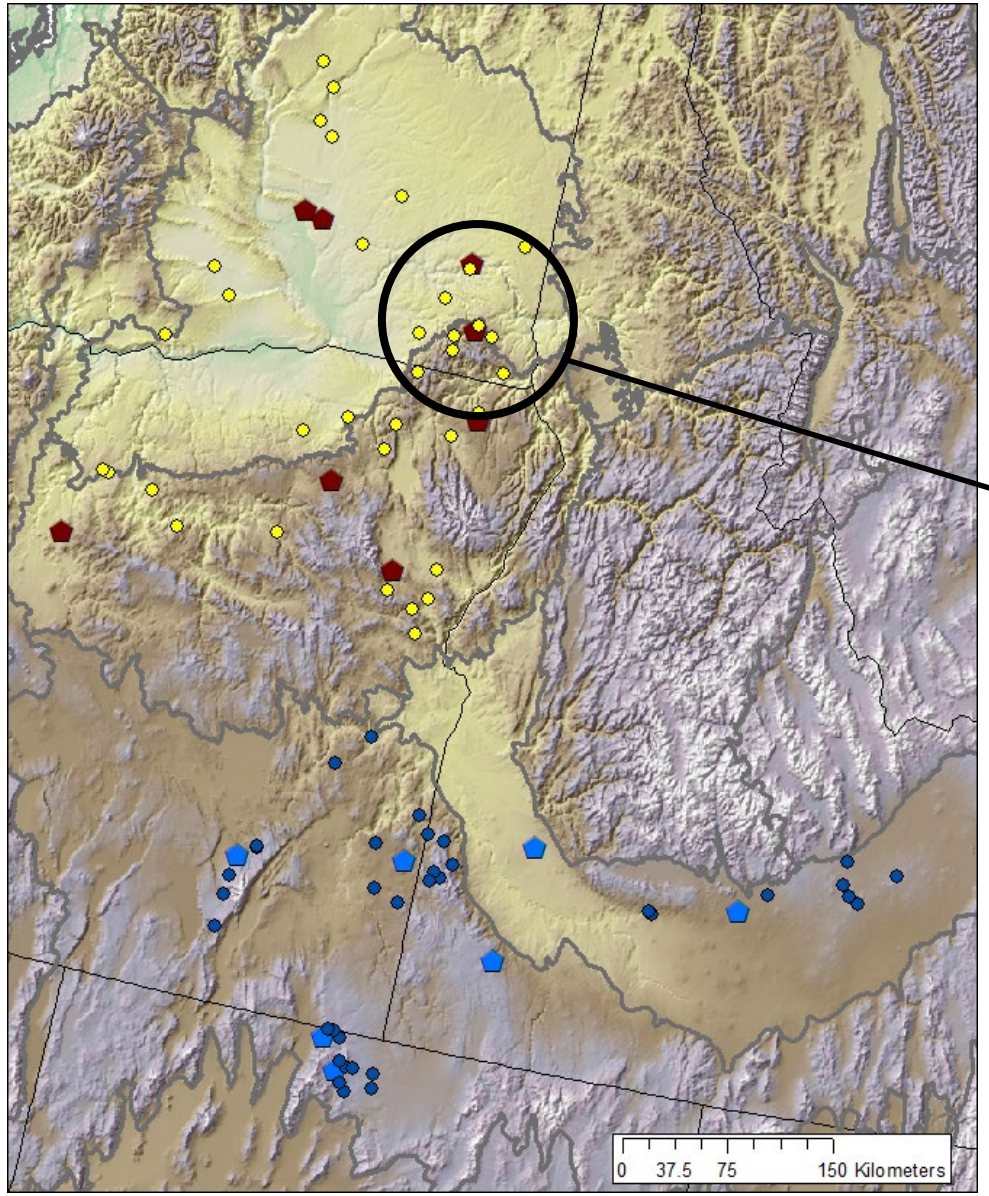

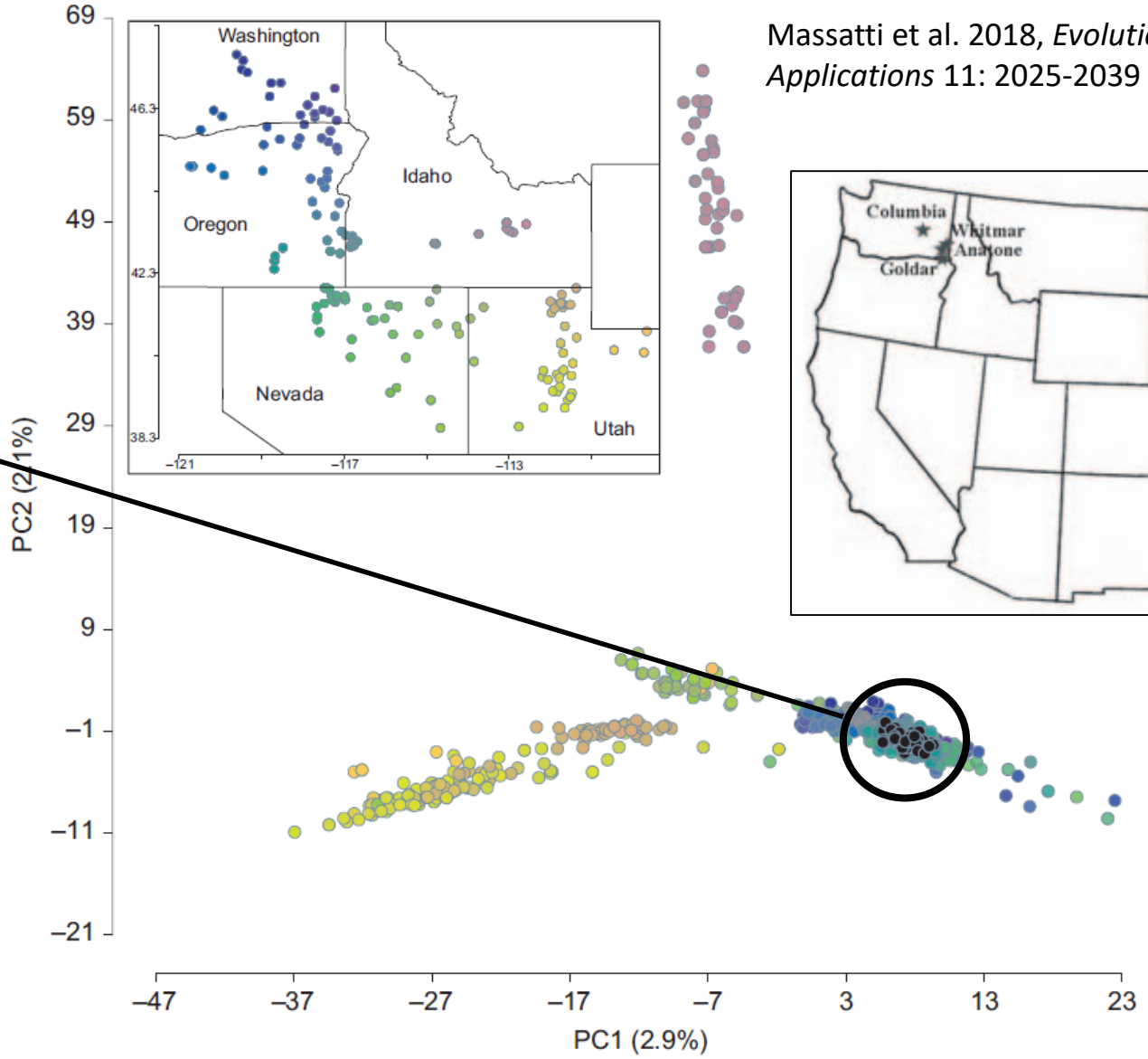

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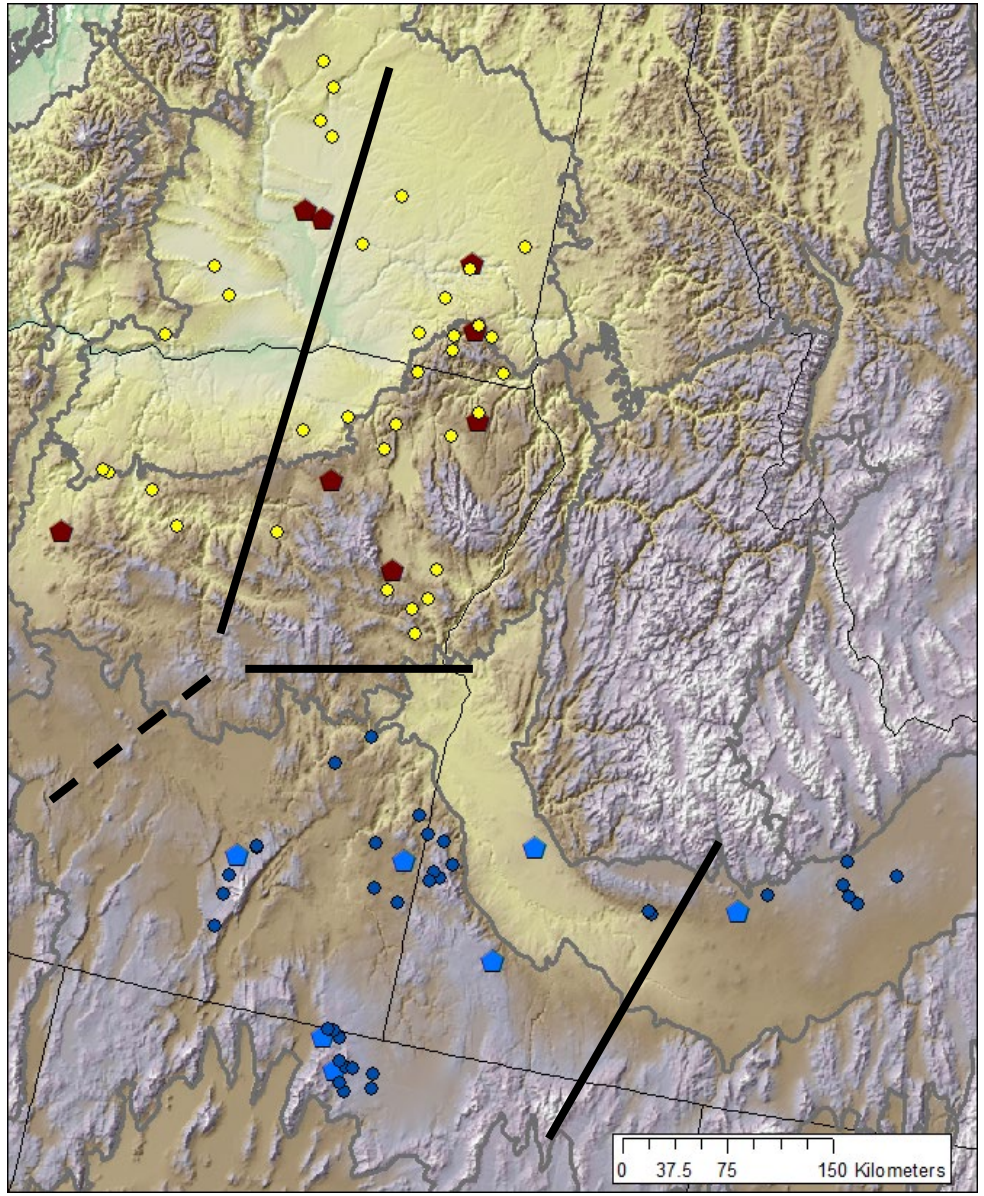

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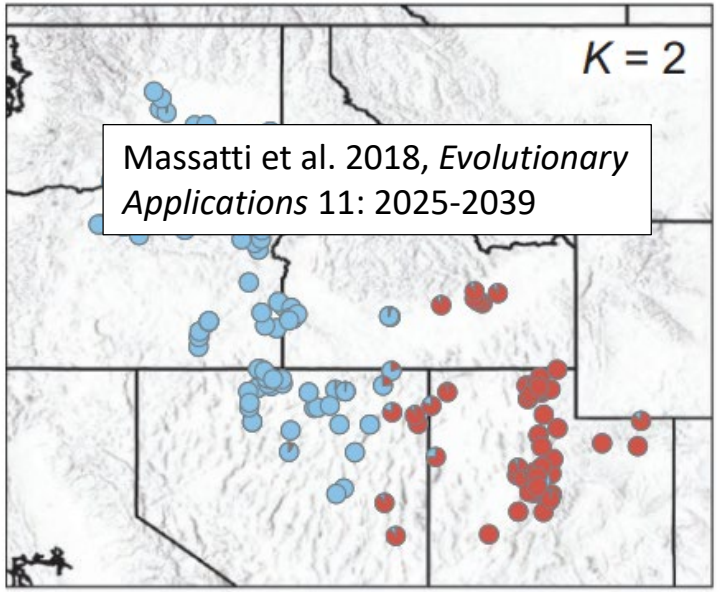
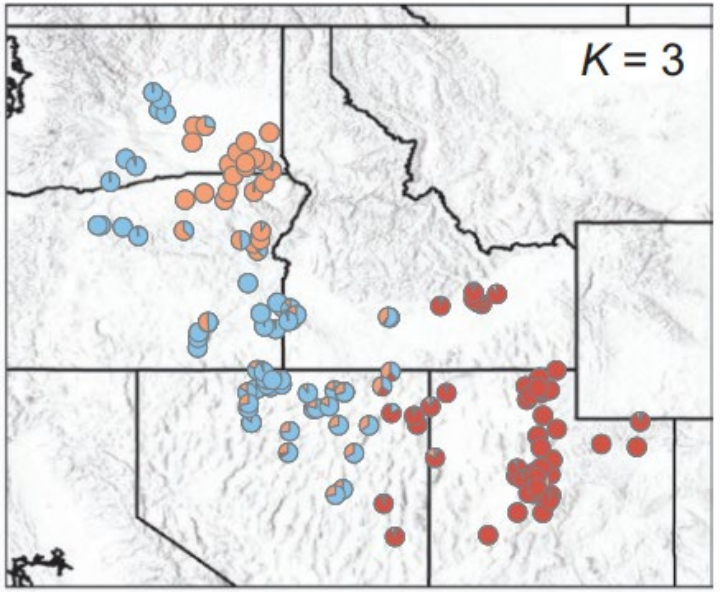
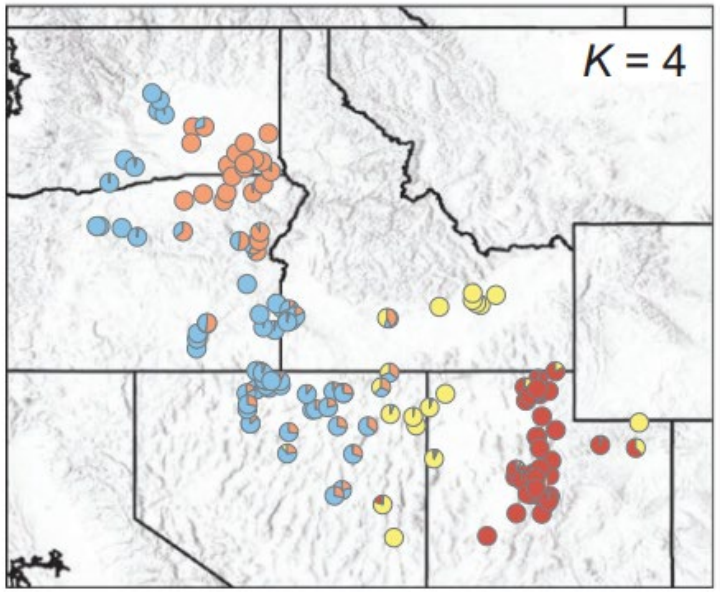
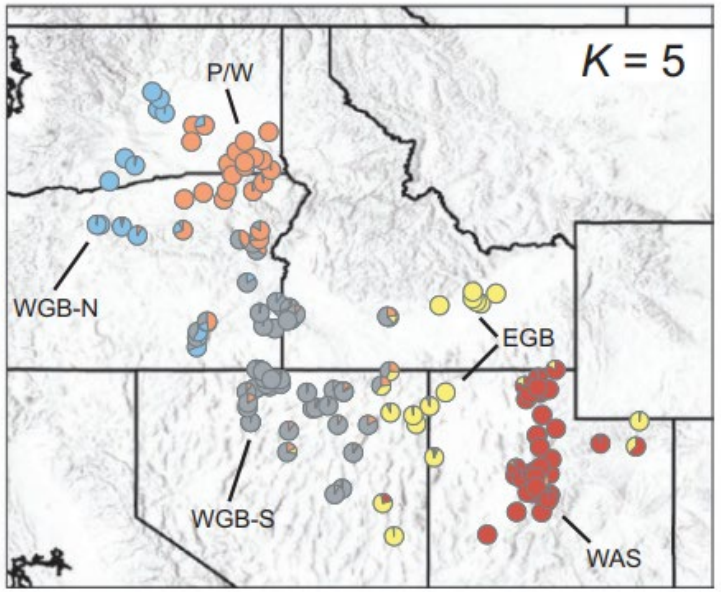
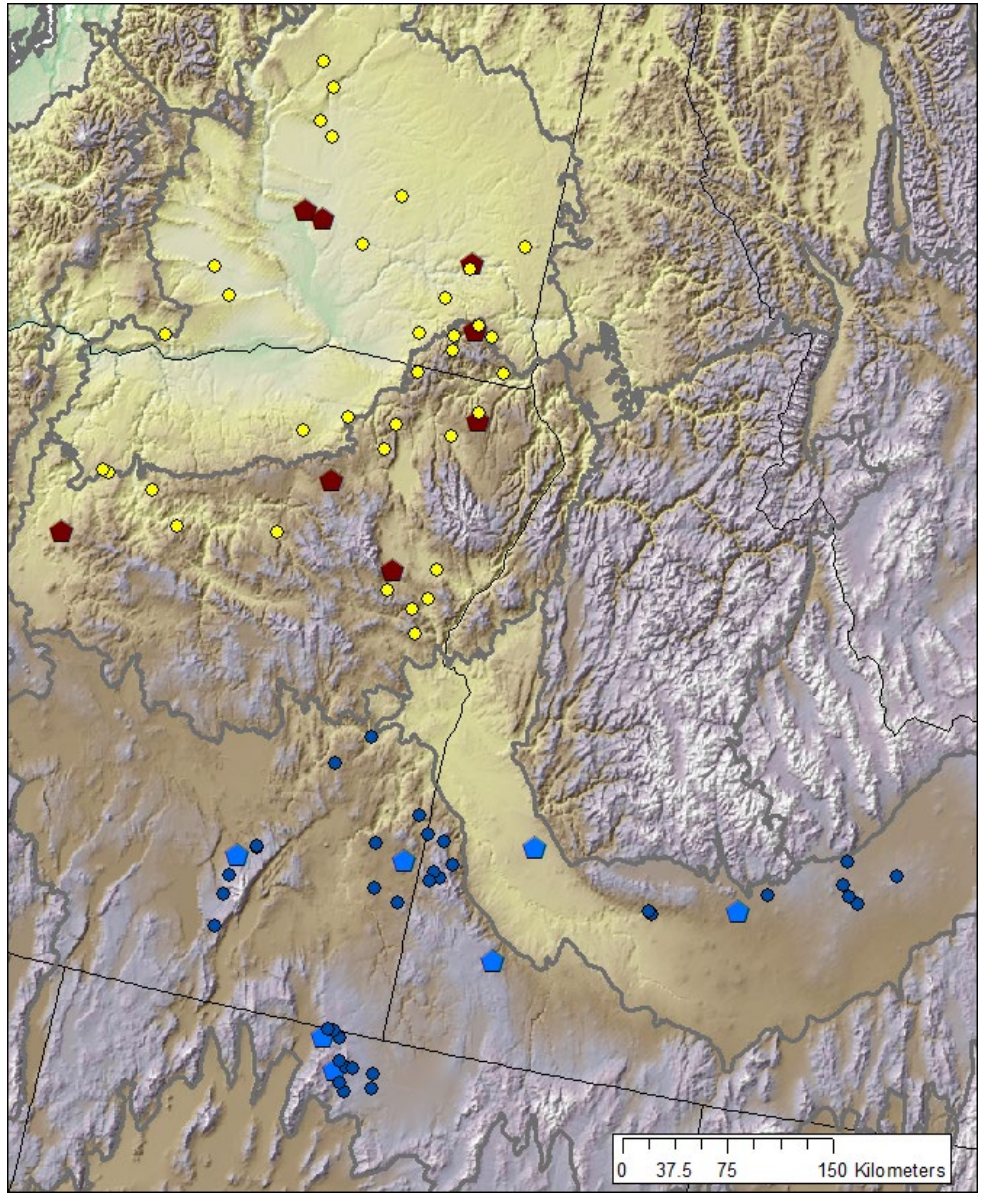


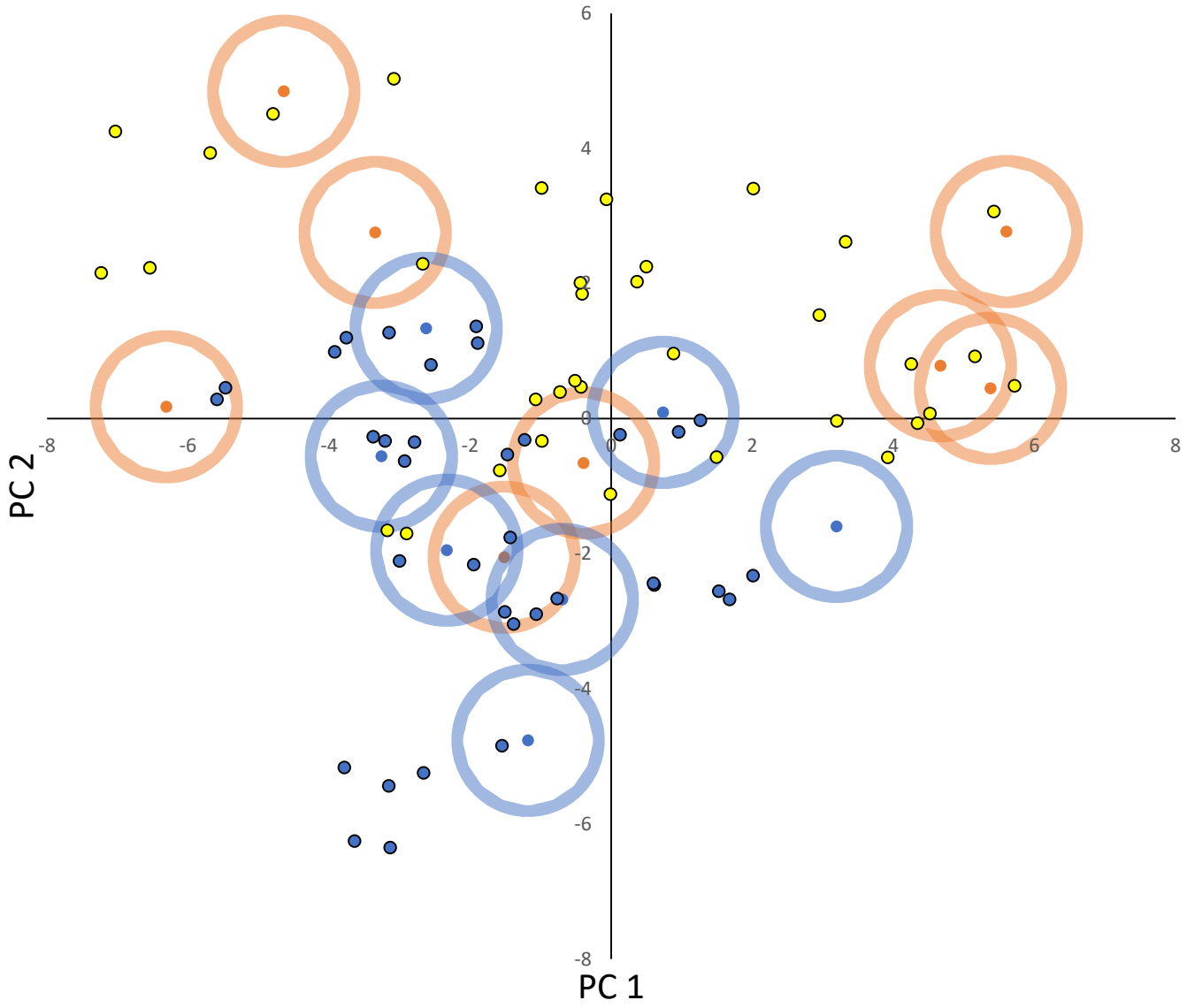






Bluebunch wheatgrass – Variation between gardens





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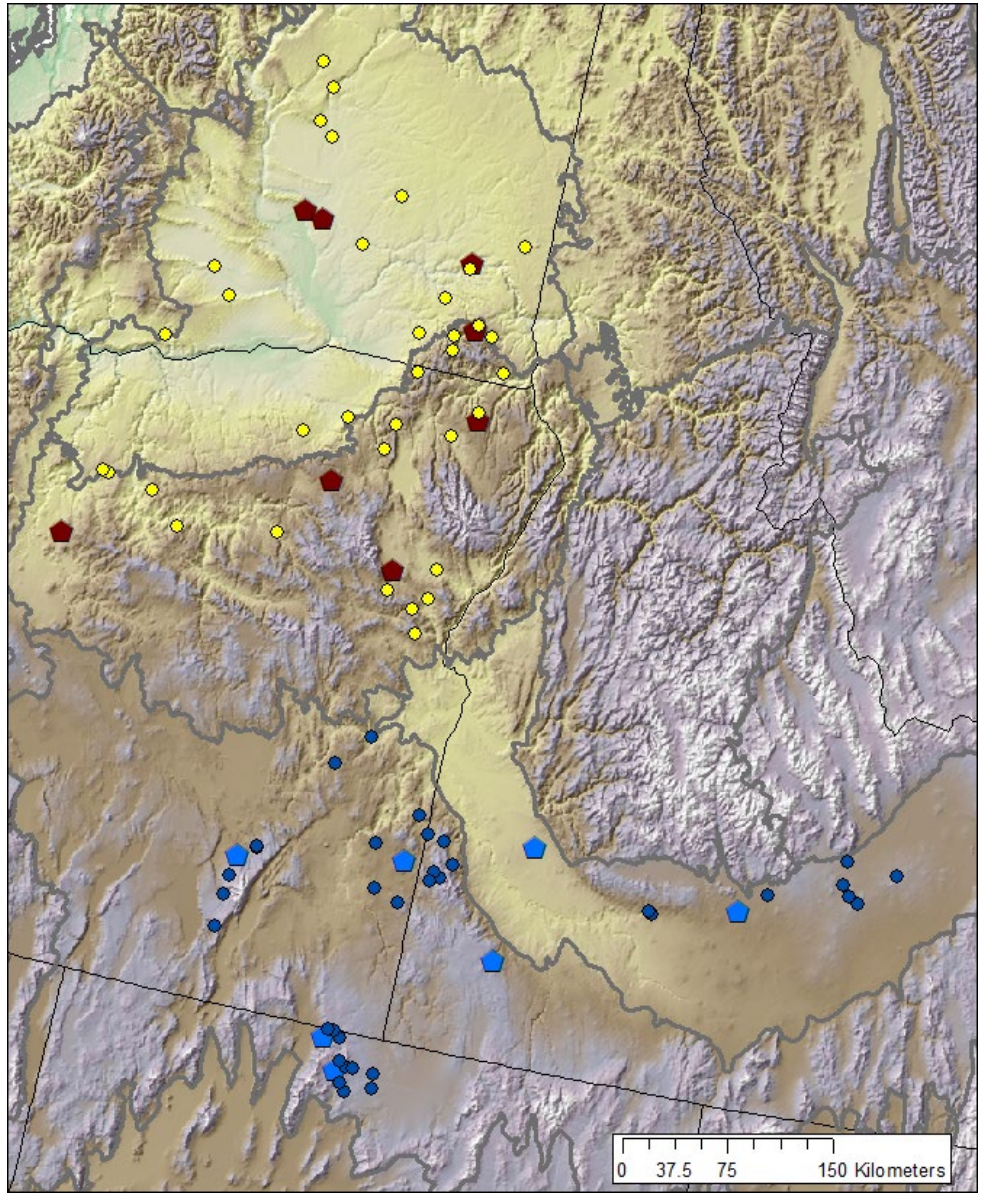

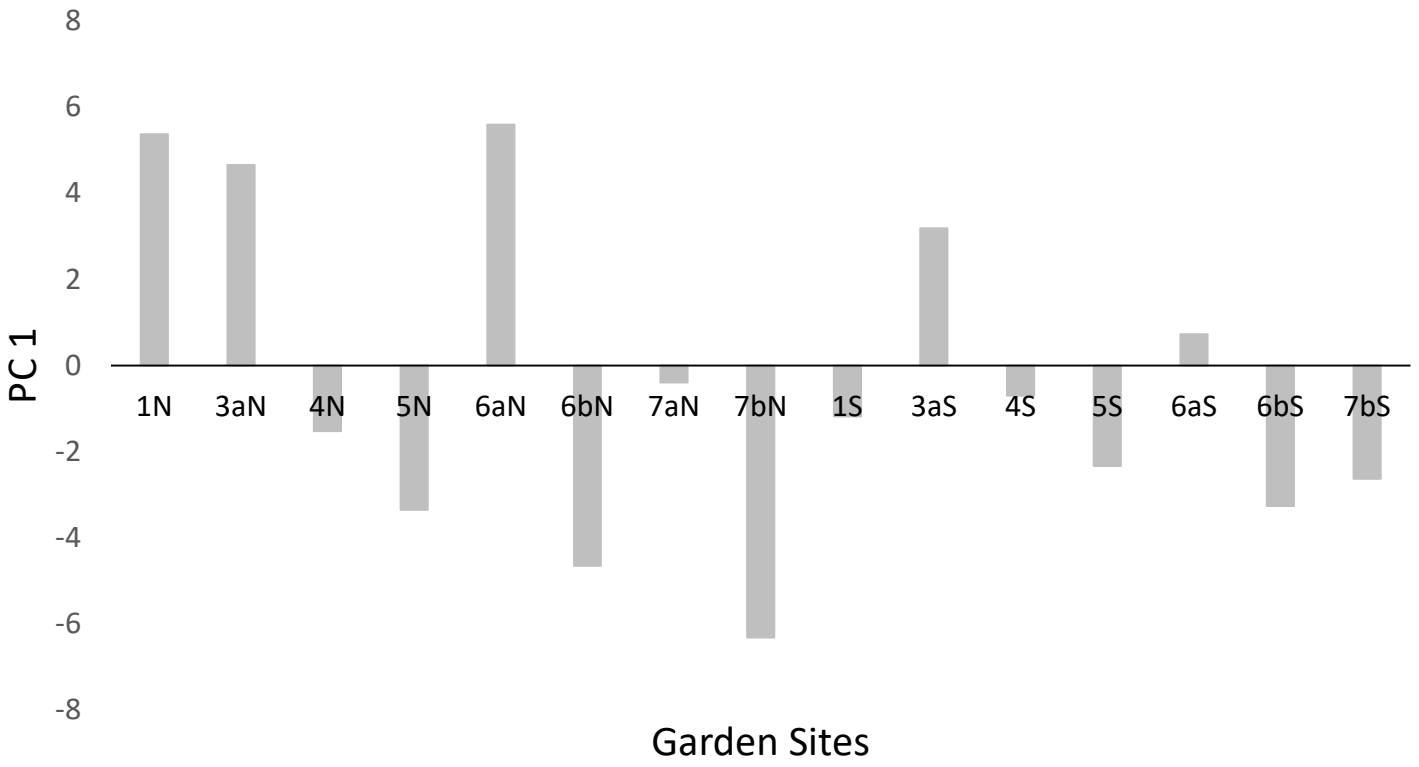

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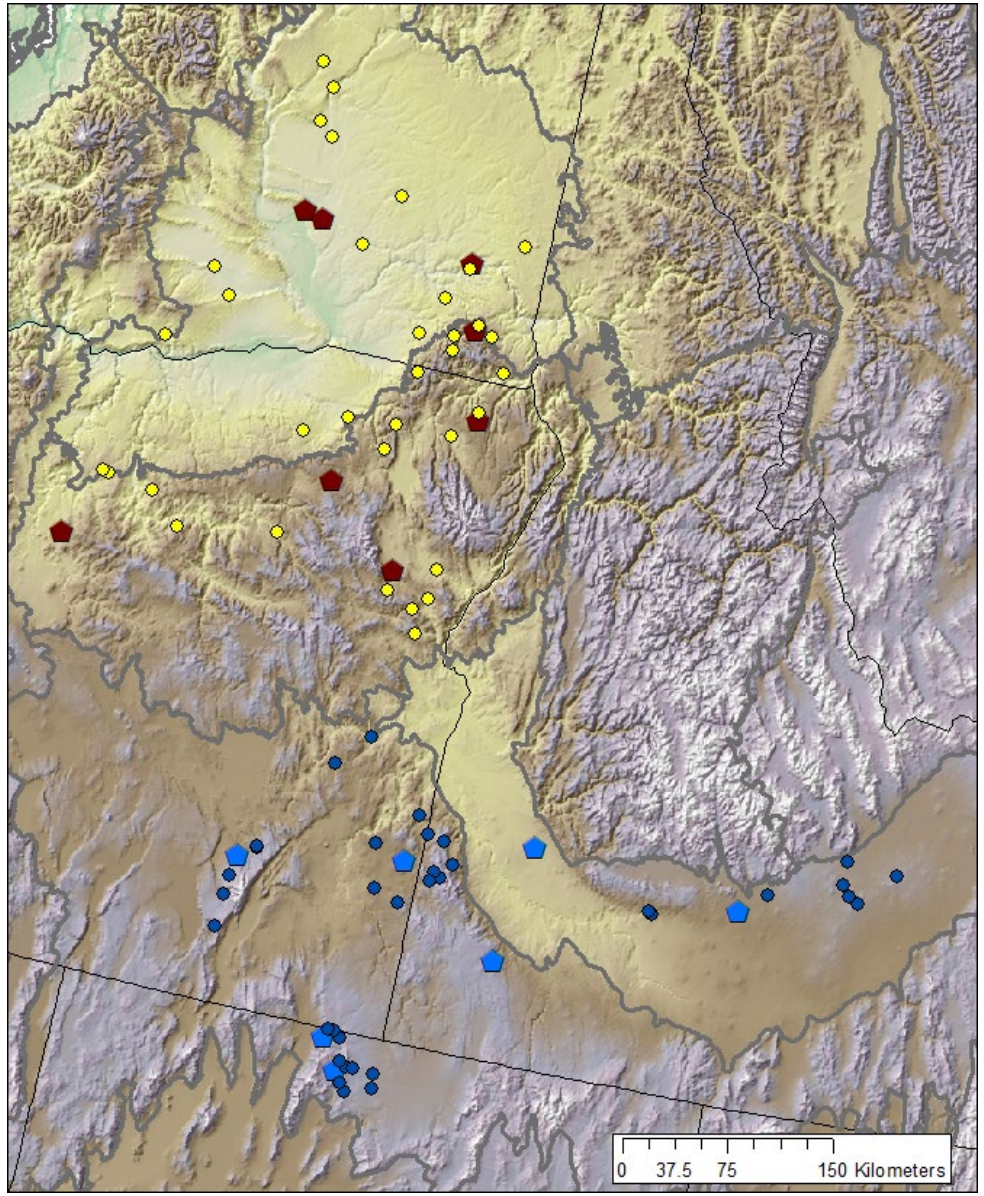
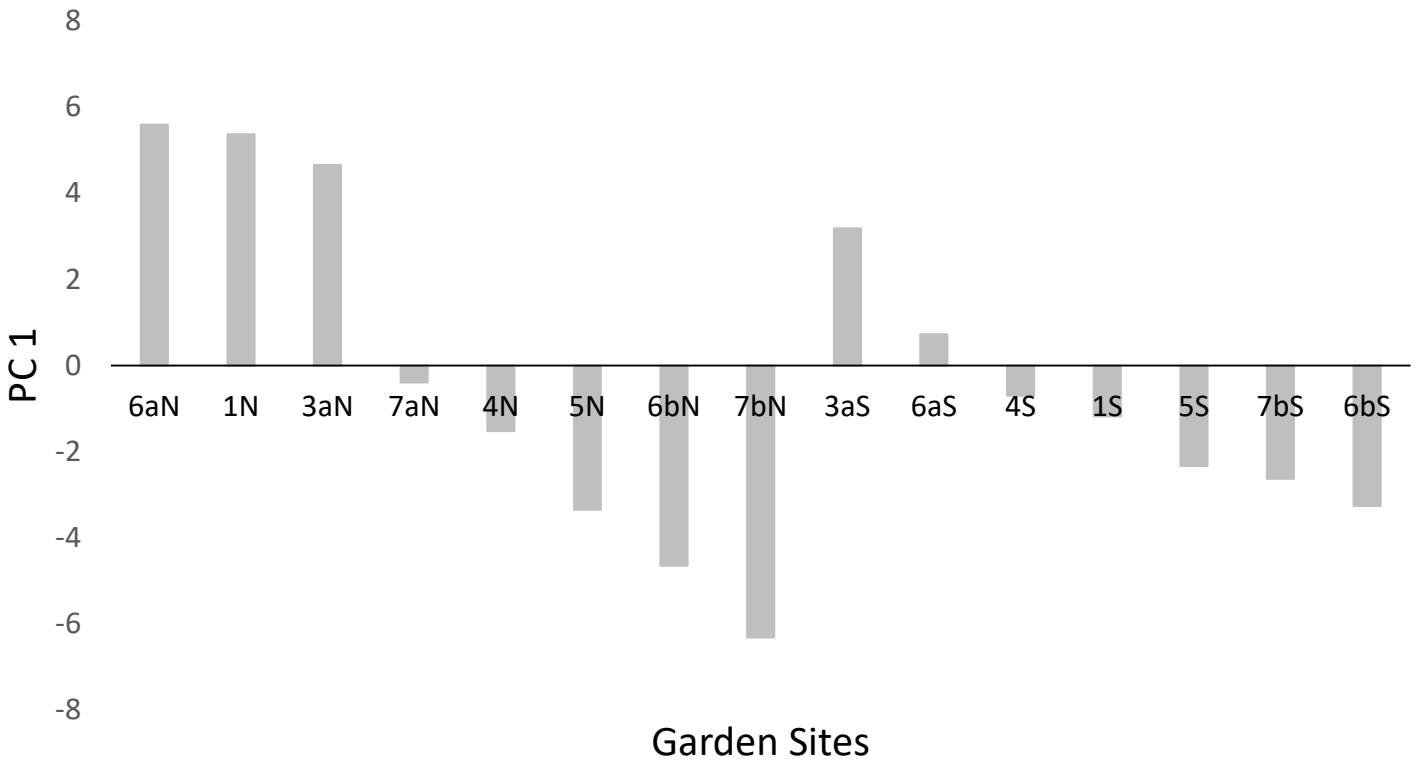
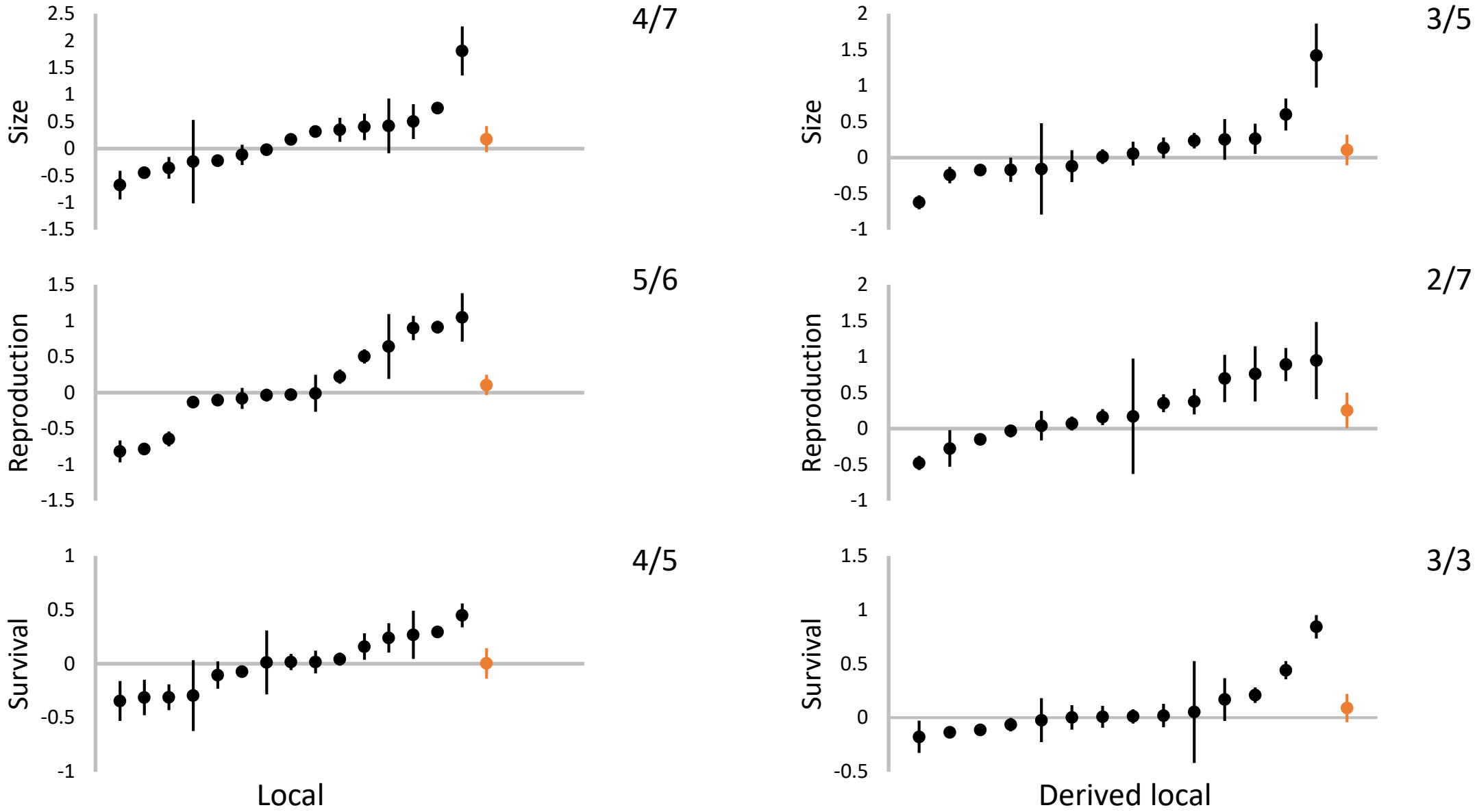




Bluebunch wheatgrass – Evidence of local adaptation



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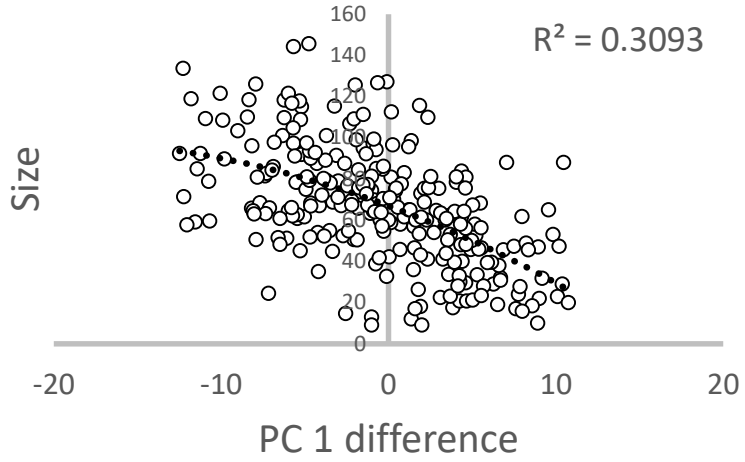
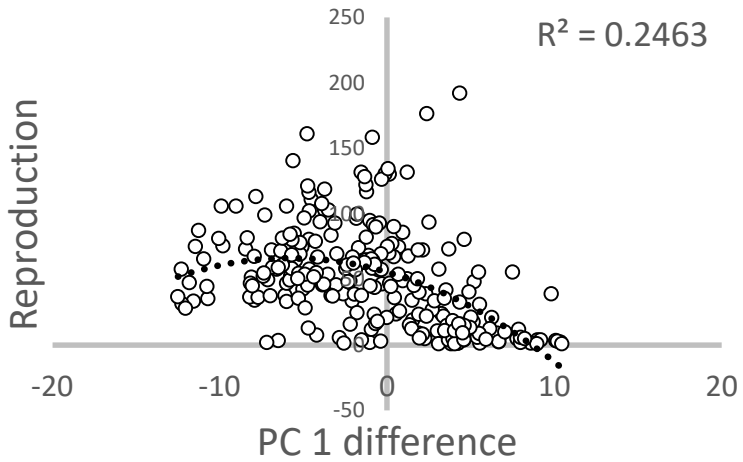
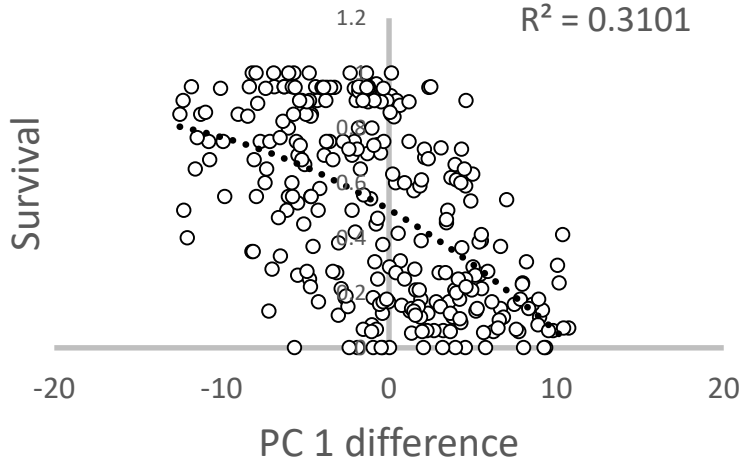
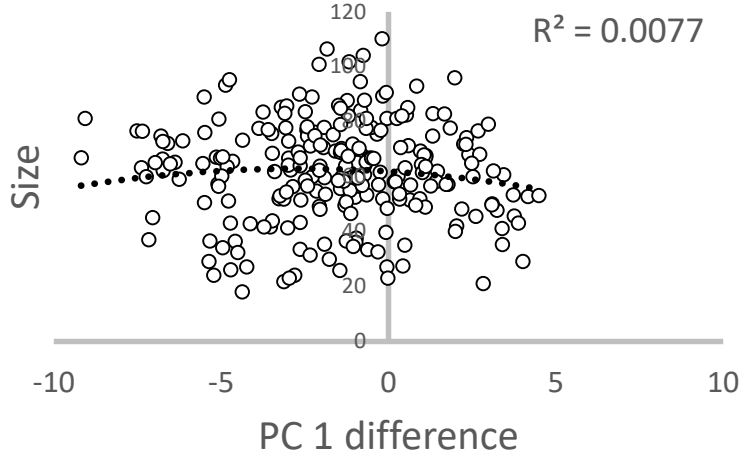
Northern gardens

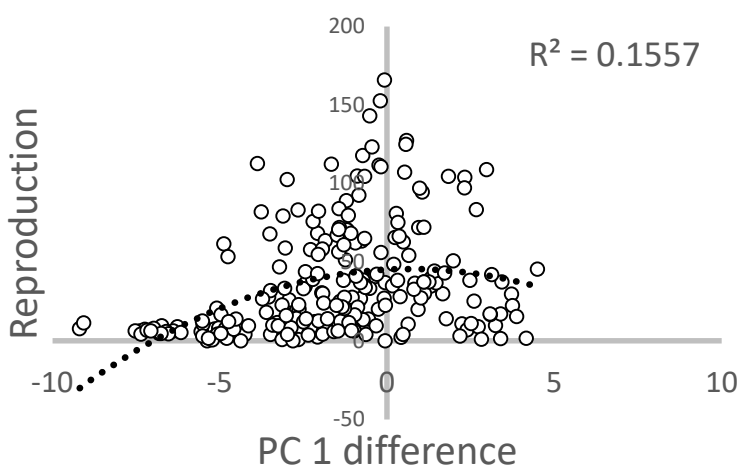


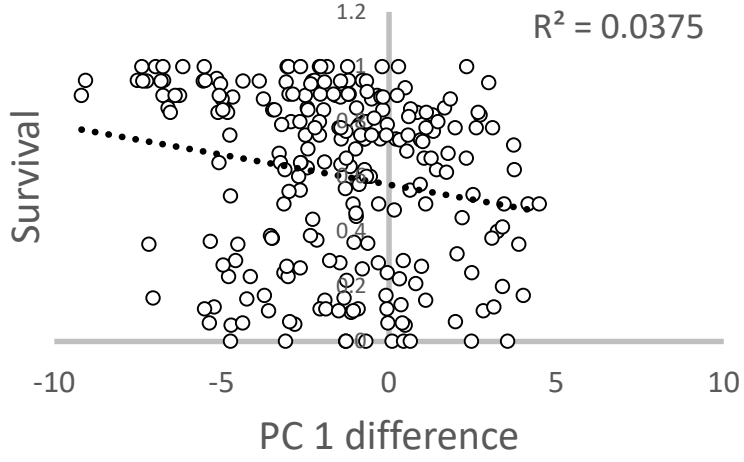




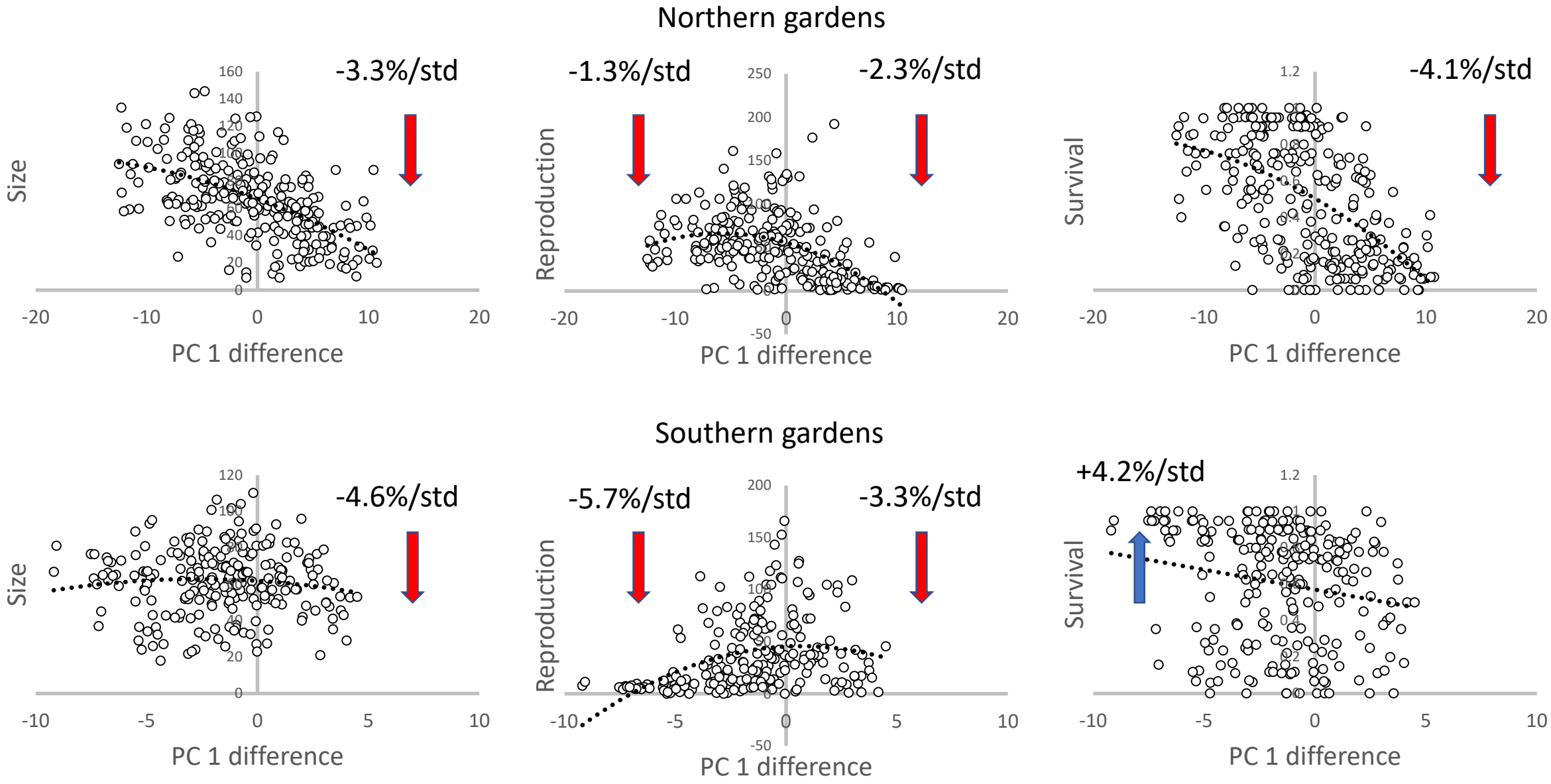
Southern gardens



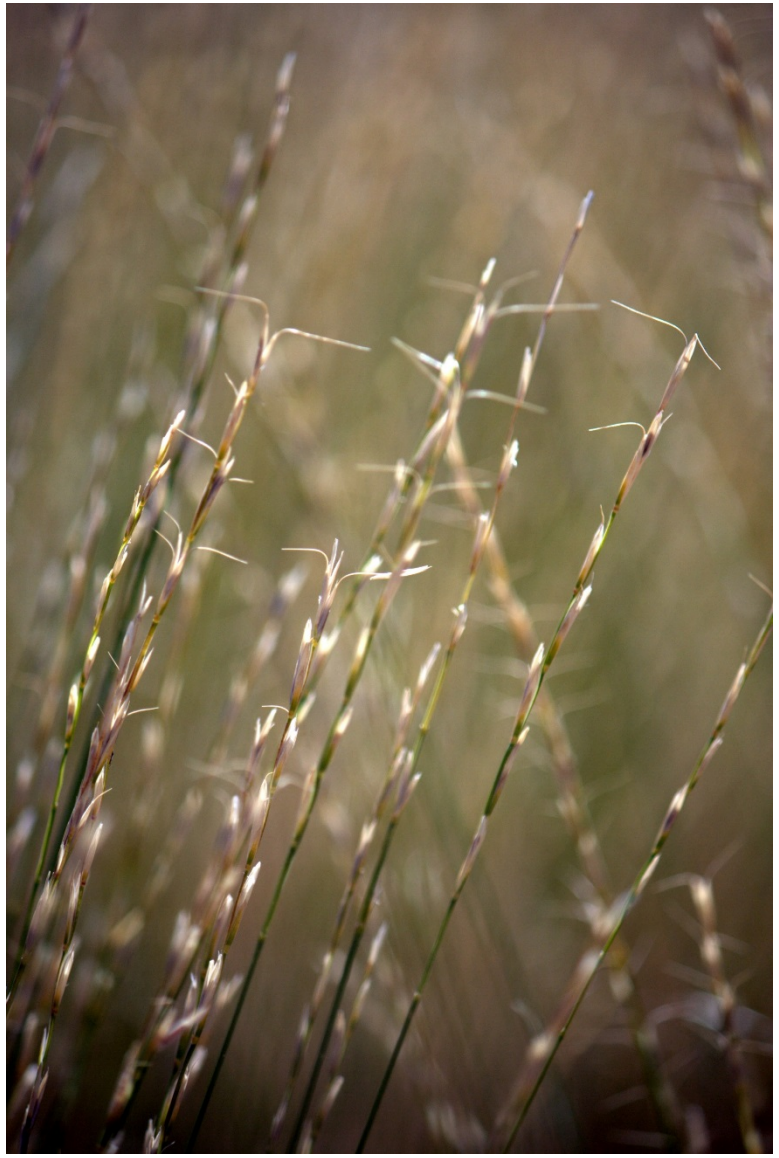




Bluebunch wheatgrass – Scale of local adaptation



Bluebunch wheatgrass – Summery



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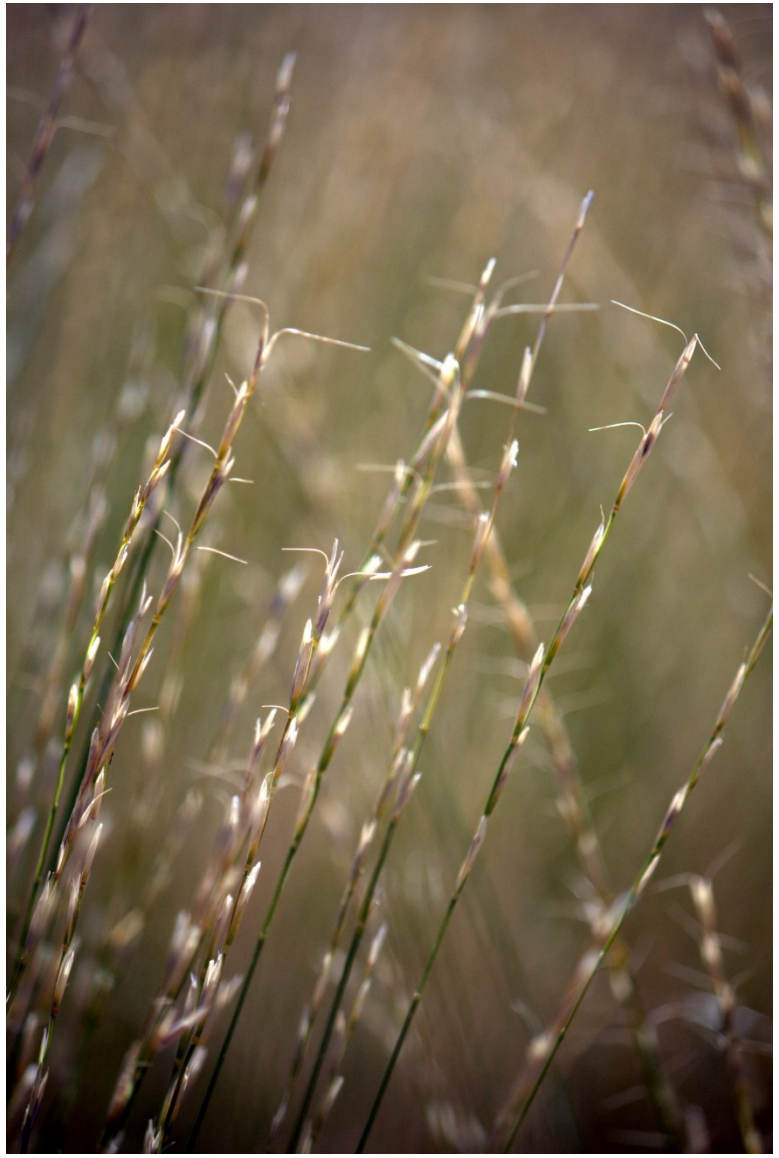

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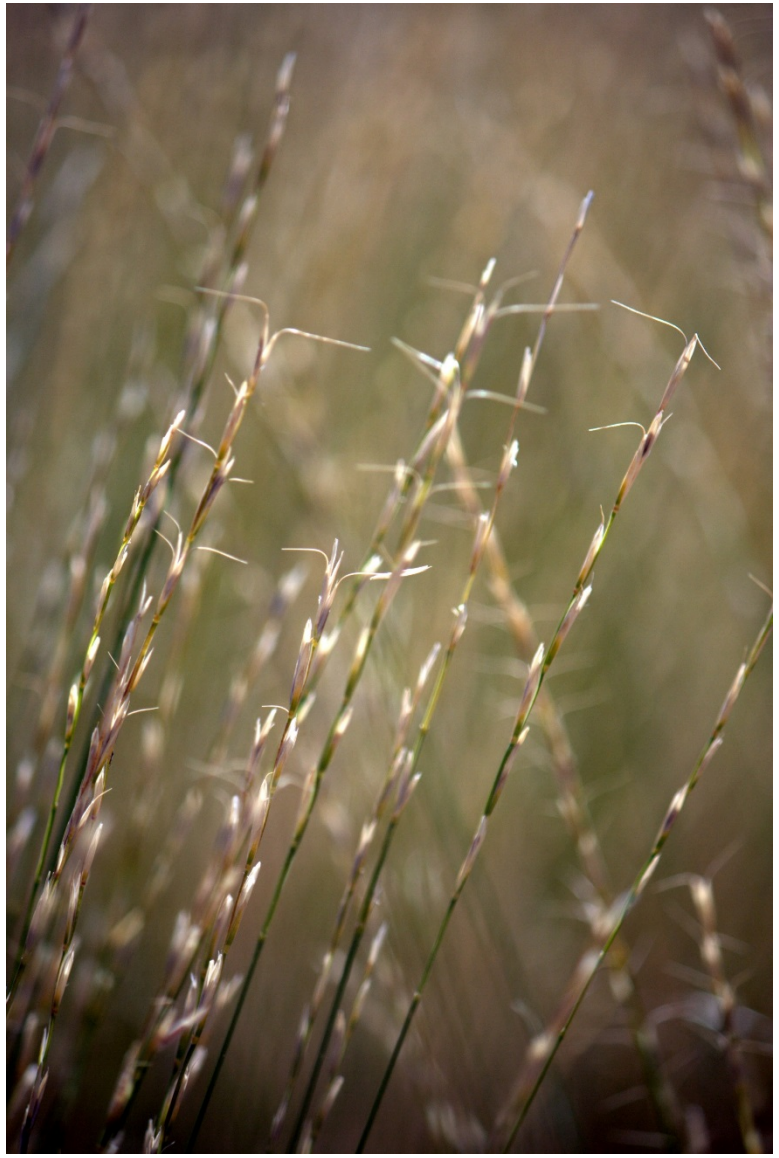

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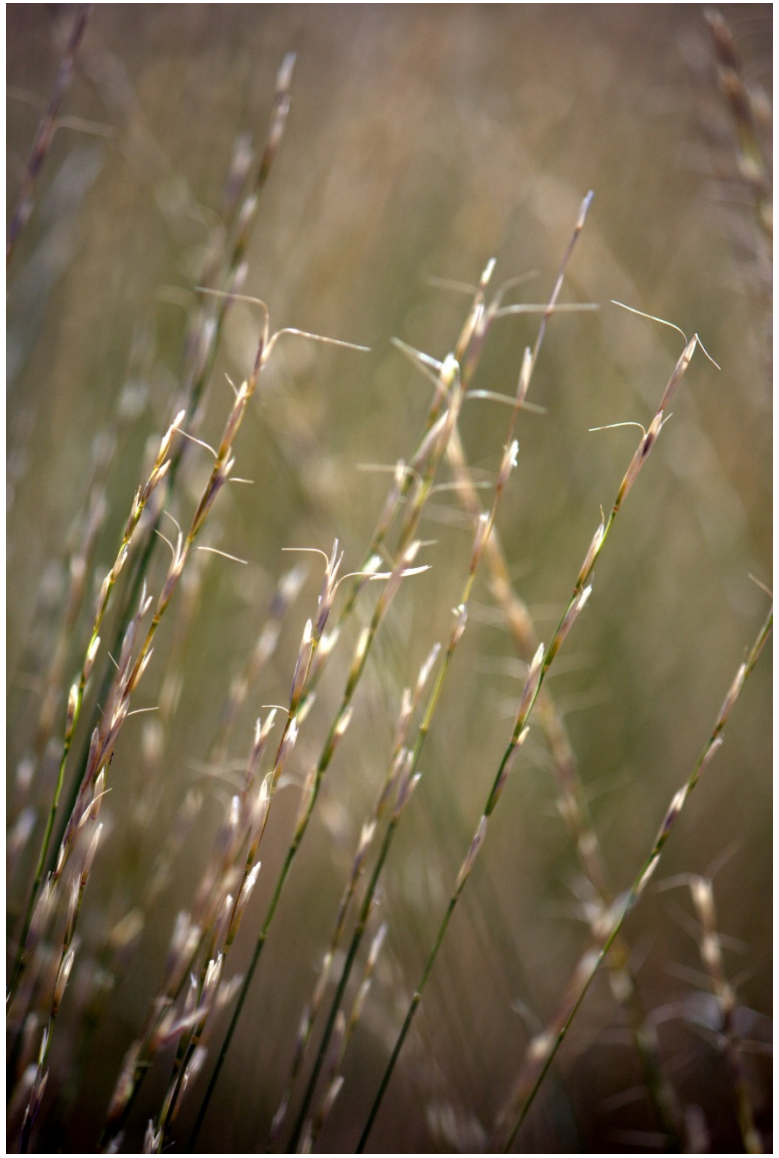
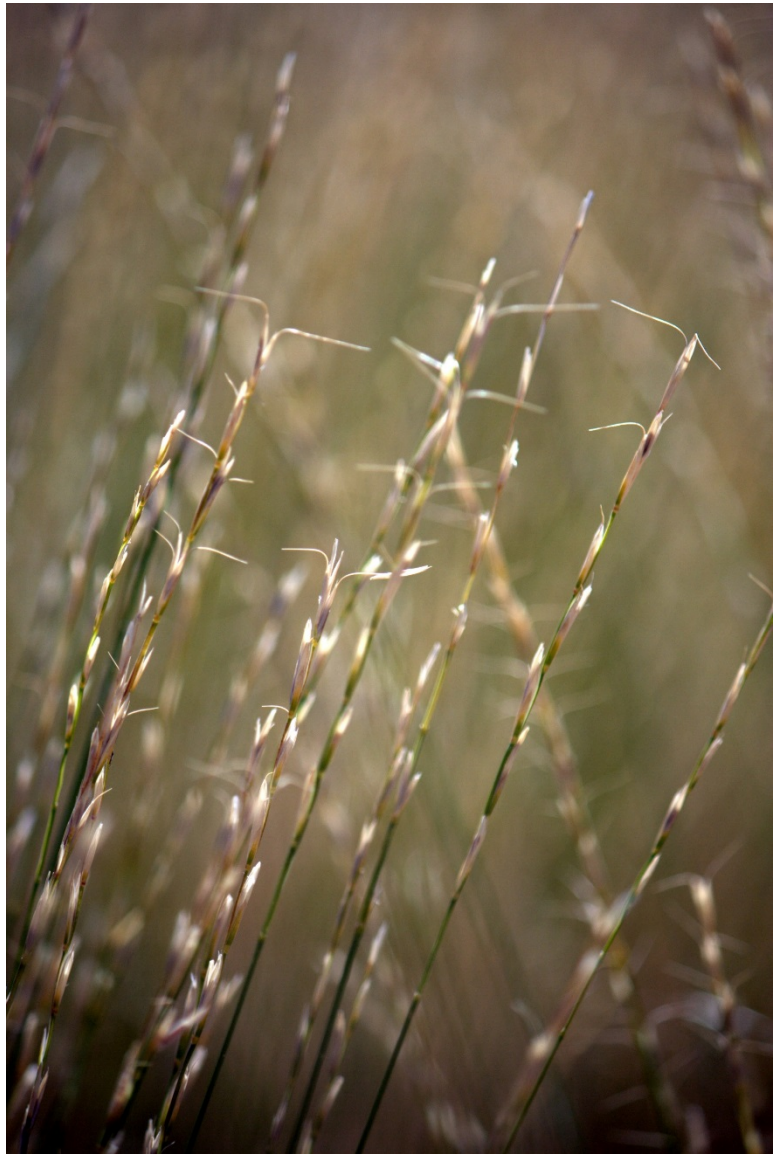
- Is there local adaptation? – Yes. Though it is weak on a per garden basis and there is some maladaptation as well.
- Are there any patterns to local adaptation? Yes! While there was evidence that local did better, mostly populations from hotter and drier conditions than a given garden did worse. The signal was neutral to mixed for populations from cooler and wetter conditions.

Bluebunch wheatgrass – Summery



- How well did the gardens capture climatic variation? - Quite well! However, they do not precisely match representative seed zones. Also, not all climate space of the populations was covered by gardens.
- Is there local adaptation? – Yes. Though it is weak on a per garden basis and there is some maladaptation as well.
- Are there any patterns to local adaptation? Yes! While there was evidence that local did better, mostly populations from hotter and drier conditions than a given garden did worse. The signal was neutral to mixed for populations from cooler and wetter conditions.
- What is the scale of adaptation? A range 1.3-5.7% loss in relative fitness occurred for every standard deviation of climatic distance from garden conditions, which was generally worse for plants from hotter and drier conditions. This allows managers to estimate risk of maladaptation.

Bluebunch wheatgrass – Summery



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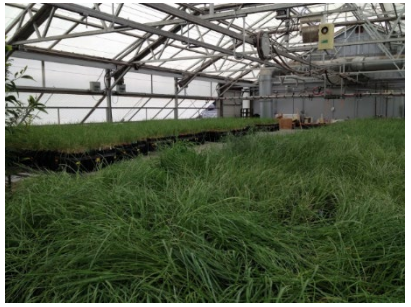
- Overall, this study shows that it is possible to determine the scale of local adaptation and determine the risk of maladaptation to current and changing climates. For species of high restoration importance we should not use “rules of thumb.”

Implications for common garden study design

- Literature suggests that 50 populations and 20 garden sites are sufficient for high quality modeling
- But! If sites are well distributed climatically, then number could be reduced further
- Bluebunch wheatgrass study, with 2 replicated “transects” indicates that 7-8 sites and ~38 populations are sufficient for high quality modeling
- How can this be implemented?

Wang et al. 2010, *Ecological Applications* 20: 153-163



2018

2019

2020+

Showy fleabane
(*Erigeron speciosus*)

Douglas' dustymaiden
(*Chaenactis douglasii*)

Tapertip hawksbeard
(*Crepis acuminata*)

Hoary tansyaster
(*Dieteria canescens*)

Silverleaf phacelia
(*Phacelia hastata*)

Thickleaf penstemon
(*Penstemon pachyphyllus*)

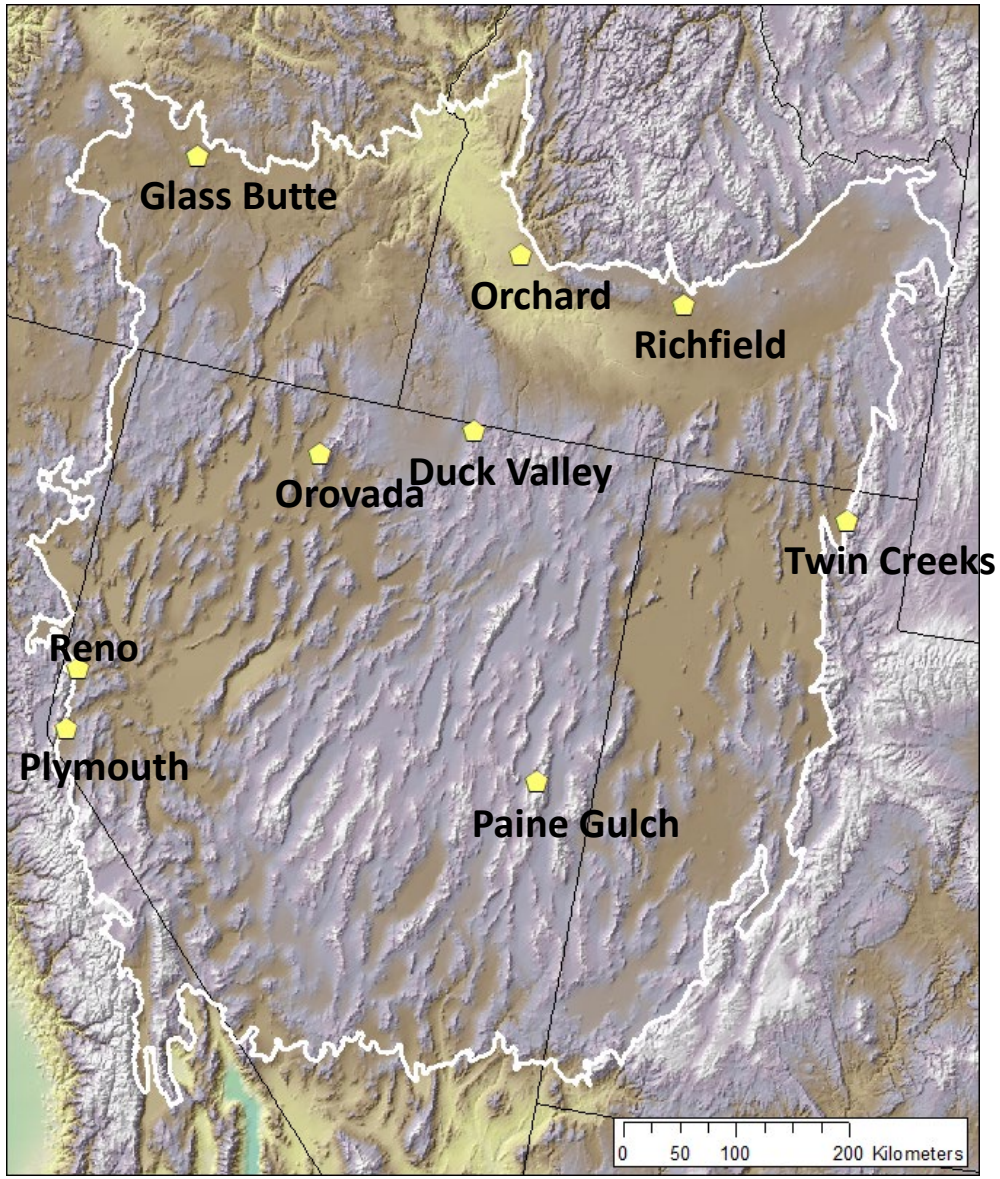
Showy goldeneye
(*Heliomeris multiflora*)

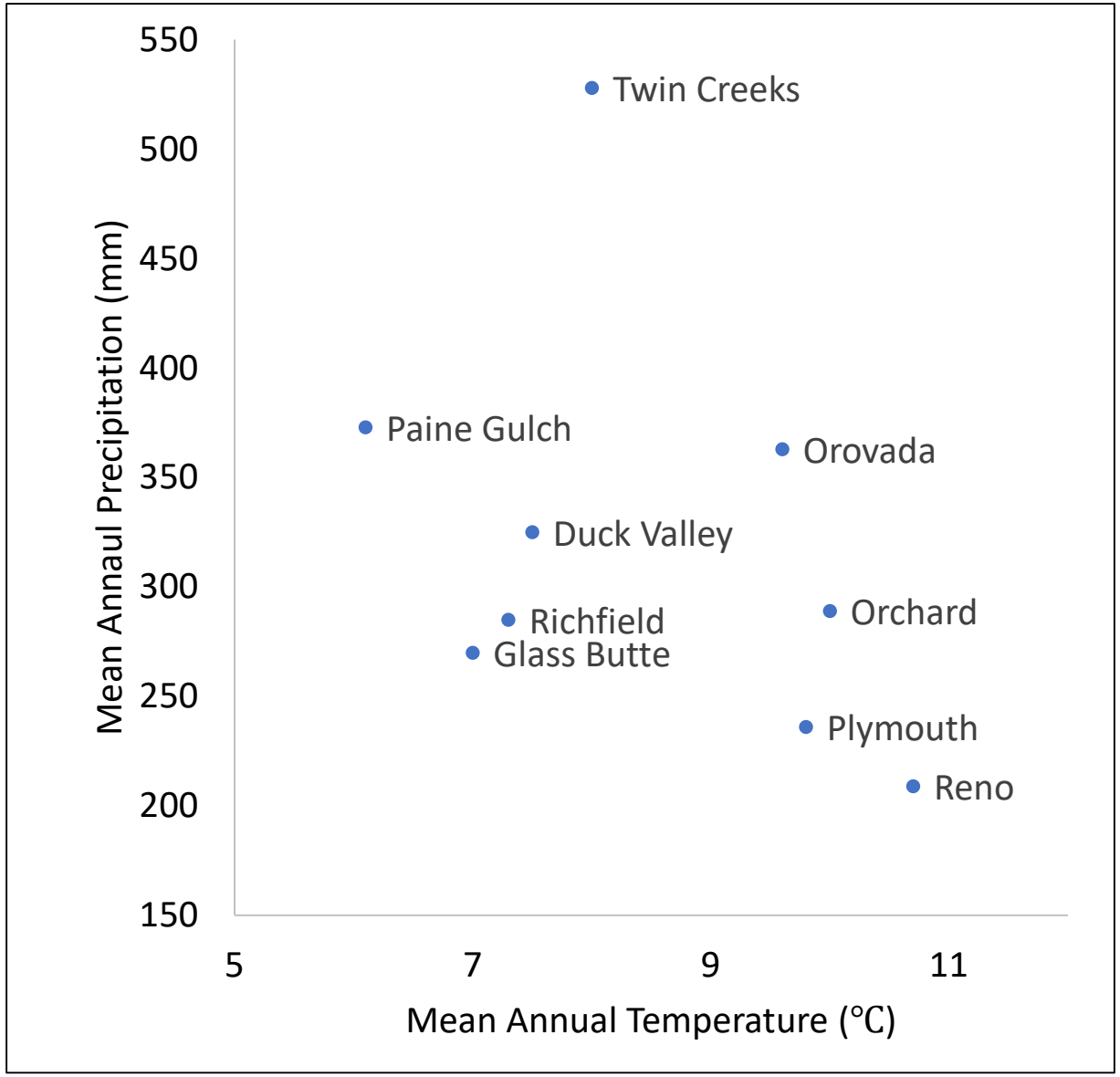
Nettleleaf horsemint
(*Agastache urticifolia*)

Globemallow
(*Sphaeralcea grossulariifolia*)

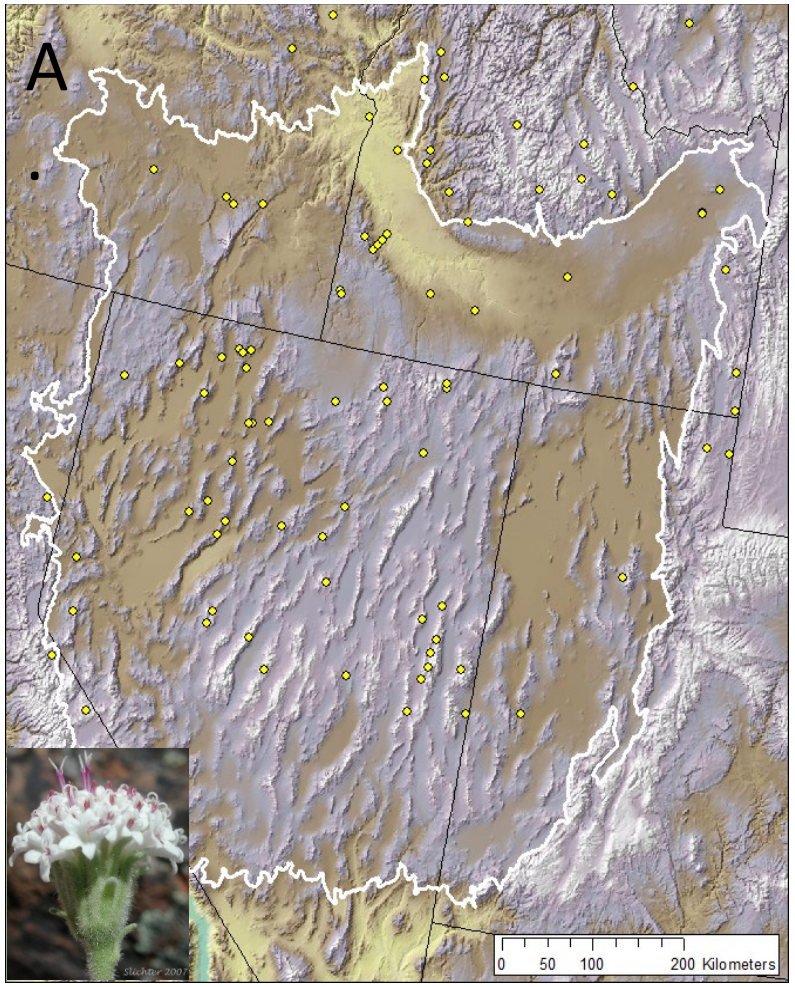
Yellow beeplant
(*Cleome lutea*)

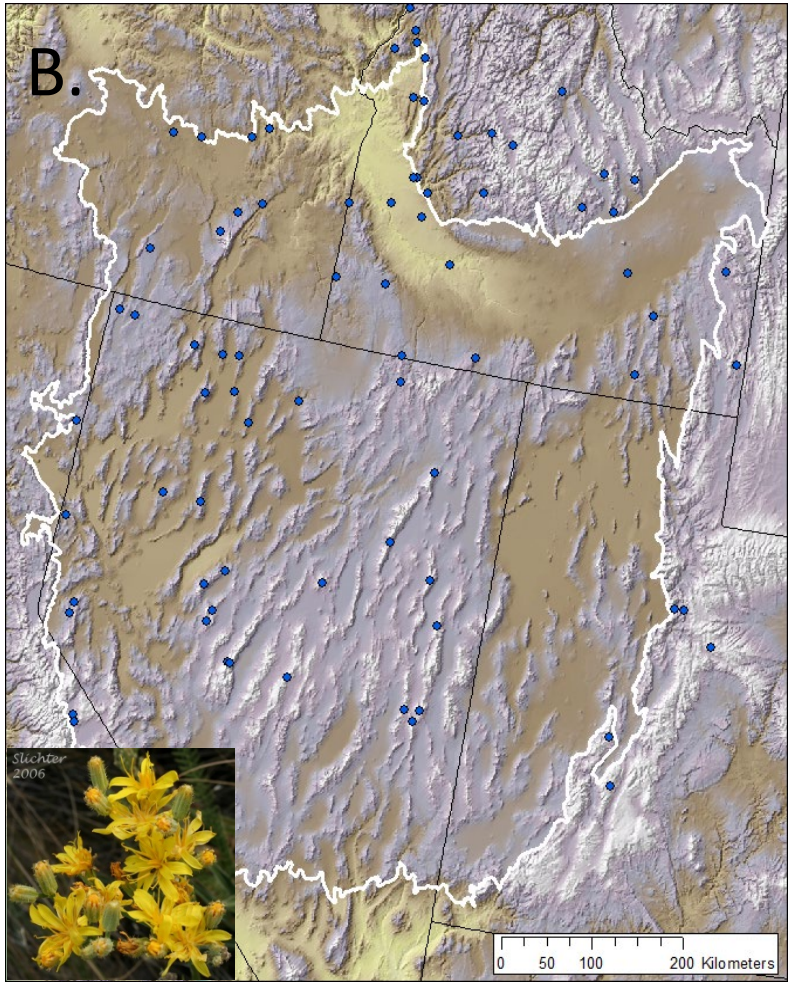
Implications for common garden study design - forbs

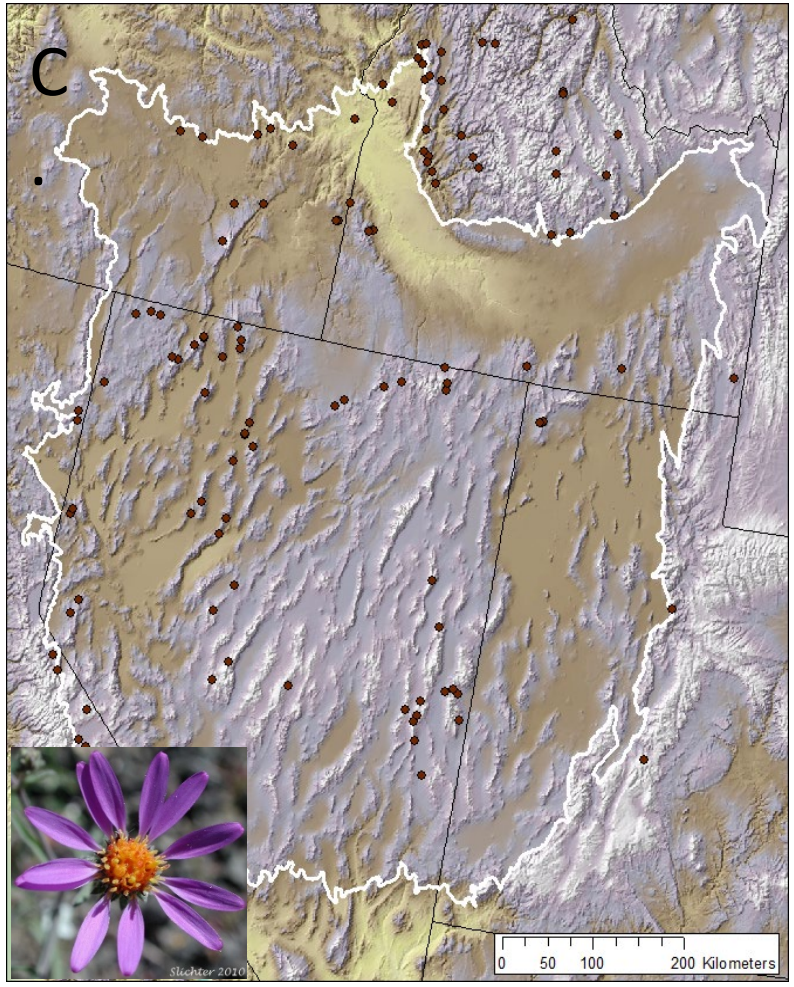




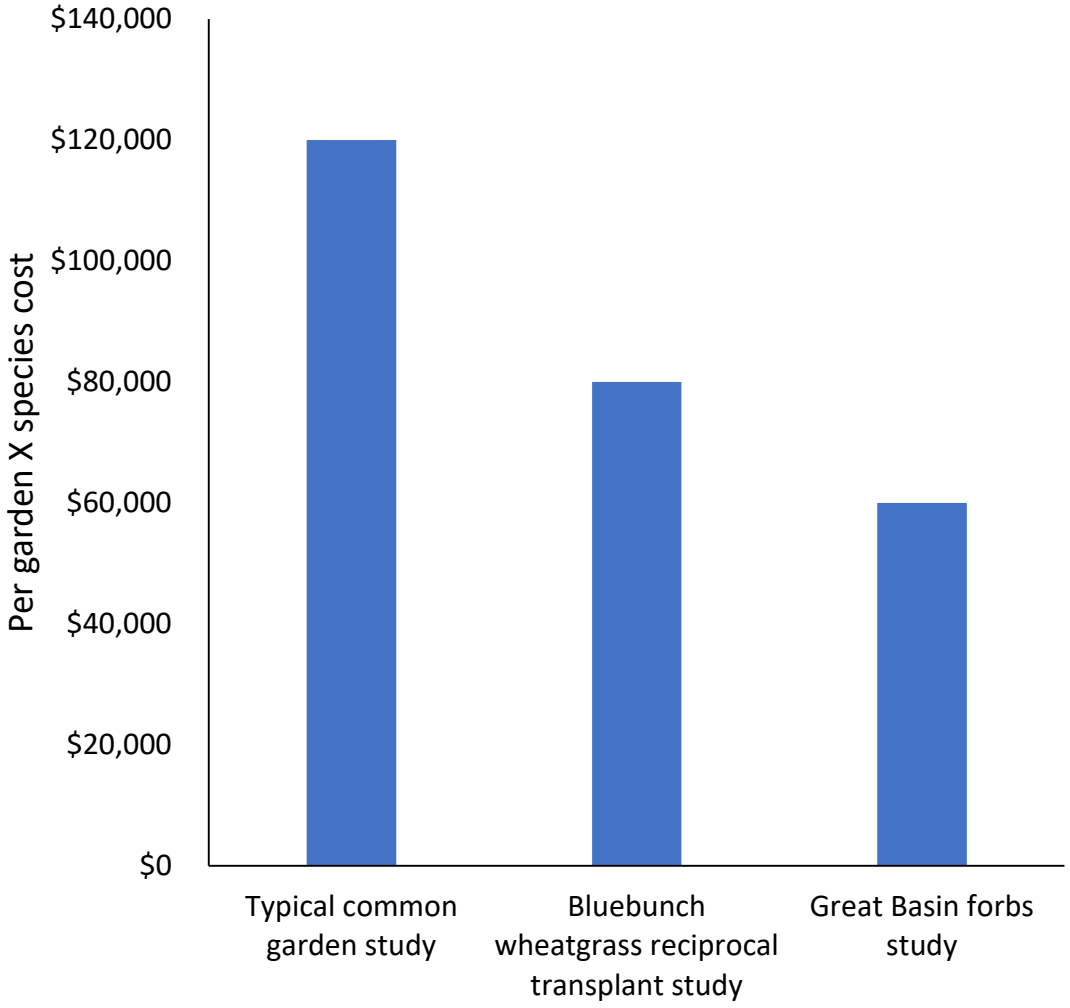
Implications for common garden study design - forbs

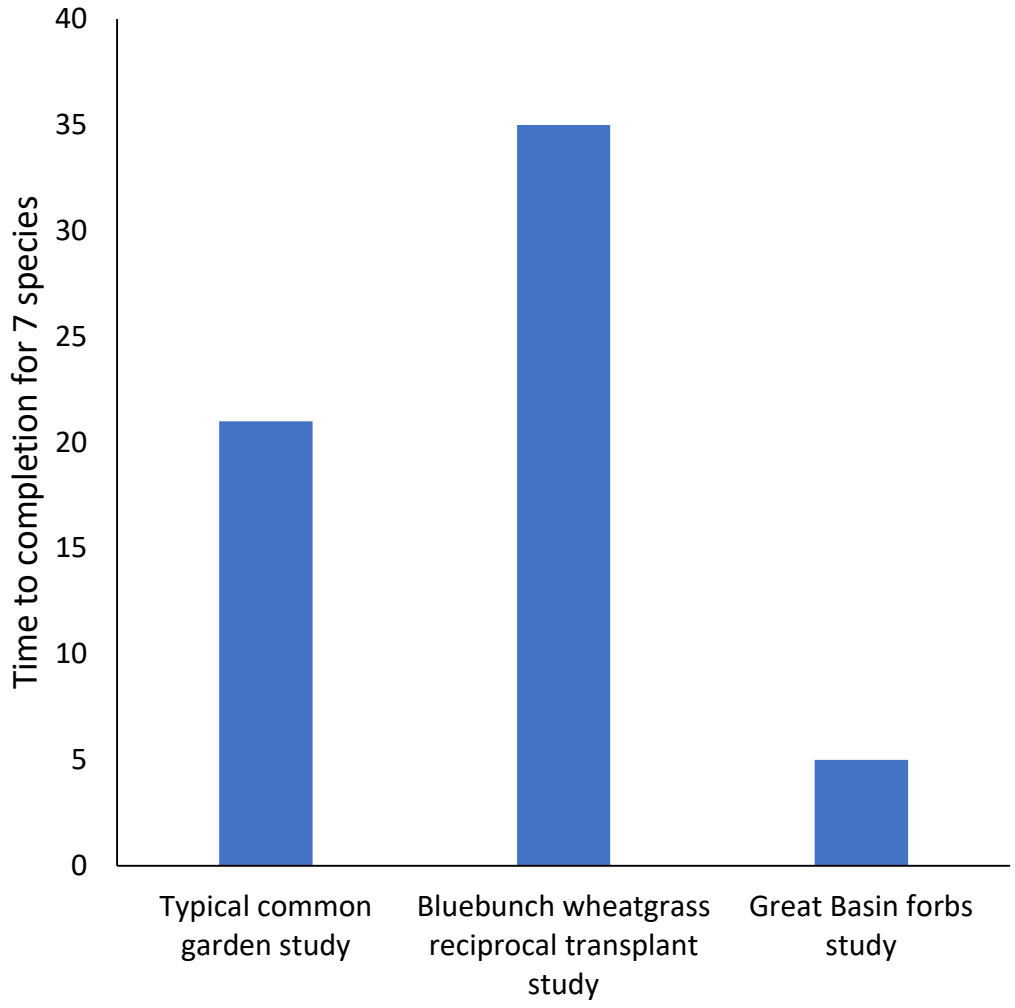




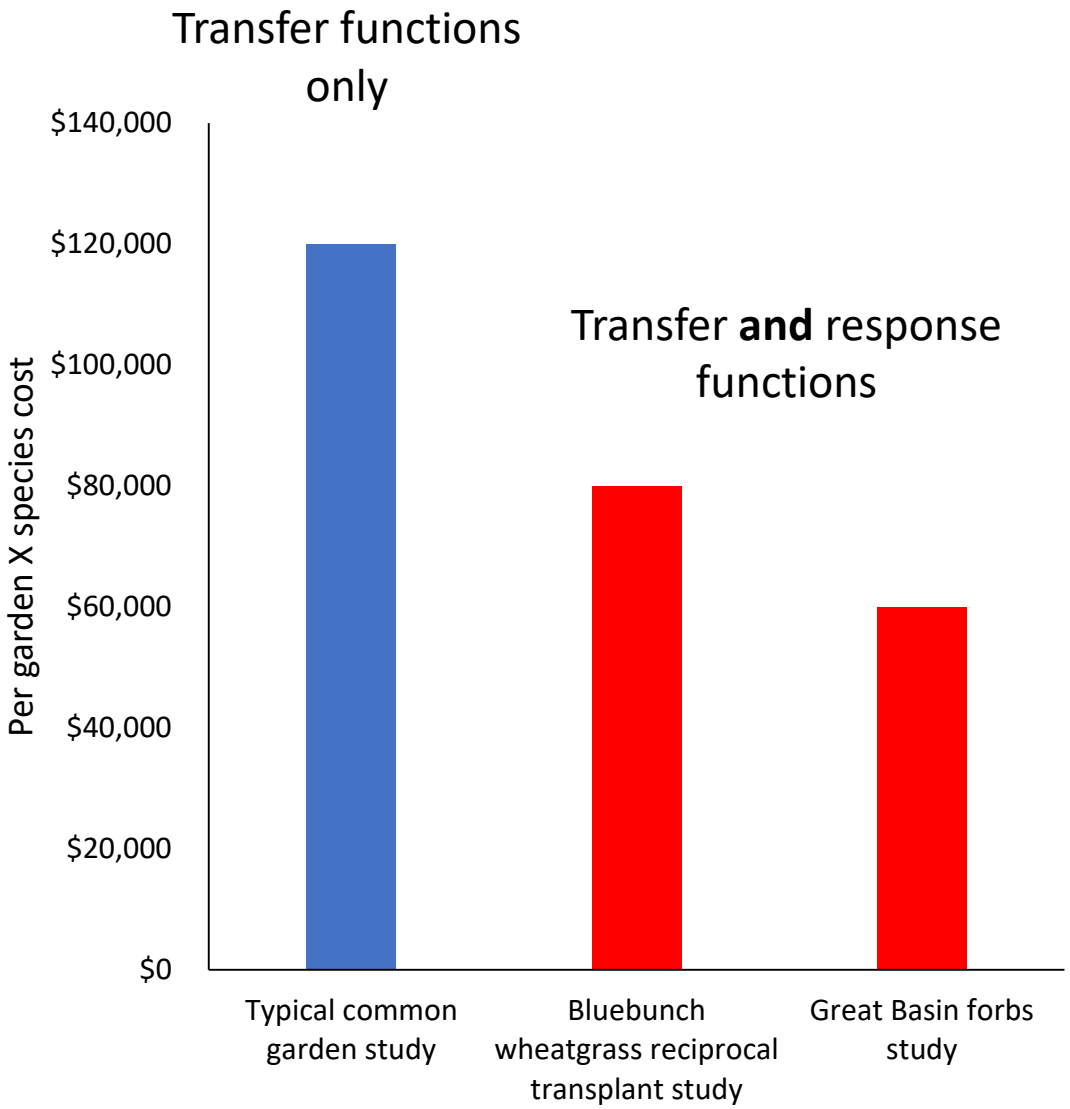


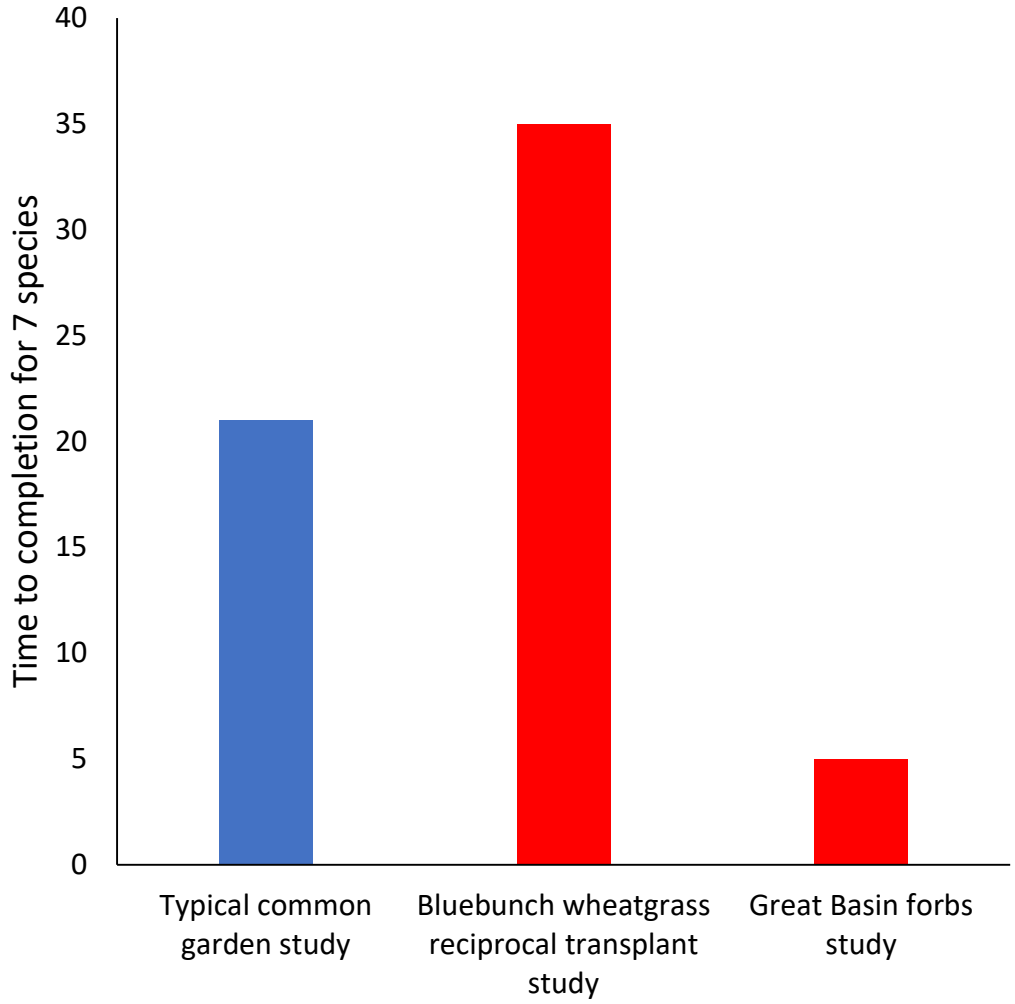
Implications for common garden study design - forbs





Implications for common garden study design - forbs





Thank you!